Compressed Air Magazine

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As It Seems To Us

THE BOOST FOR SILVER

WHATEVER its ultimate effect upon our future monetary policy may prove to be, there is no doubt that President Roosevelt's decision to buy newly mined silver will make for him many friends in the seven western states which lead in the production of the white metal. It is not usual to consider metals in the same category with crops, and yet silver is just as much a staple product of the earth in those seven western states as corn is in Iowa. The only differences are that Nature, instead of man, planted it, and that once the ground has been worked it is worthless for further mining. In any case, the producer, to continue in business, must get more for his yield than it costs him to extract it.

All mining ventures are gambles, and this is particularly true of silver mining. In recent years the industry has been at such a low ebb that virtually all out-and-out silver mines in the United States have been forced to shut down. A lot of silver has been produced, but practically all of it has been a by-product of other metals—chiefly copper, lead, and gold.

From 1891 to 1895 Colorado's hillsides disgorged 120,310,799 ounces of silver, but from 1921 to 1925 they produced only 25,843,389 ounces, a drop of nearly 80 per cent. As a result, Aspen, Creede, Silver Cliff, and other camps that were beehives of activity in the first period have today so far declined that but few of the younger generation now living in the Centennial State have probably ever heard of them. Similar instances might be cited in the cases of other Rocky Mountain states.

Just how much of a silver rush we are now to witness is uncertain. When those silver mines were compiling their impressive records, the ruling price of the metal was $1 or more an ounce. The Colorado Metal Mining Association has determined the average production costs in that state to be 65 cents an ounce, which would indicate that Creede, Aspen, and the other onetime buoyant silver camps are to remain ghost towns or, at best, are to remove only a portion of their shrouds.

There seems little doubt that the principal fillip will be given the gold, lead, zinc, and copper properties which produce some silver in association with one or more of these metals. Certainly, many mines that have been on the border between profitable and unprofitable operation will now have the balance weighted in their favor. This, in turn, brings an uncertain aspect of the situation to light. Will the increased production of the base metals, that appears inevitable, flood the markets and depress prices? The powers that be in Washington express the belief that such will not happen, which would seem to indicate that counteractive measures will be forthcoming when they are needed.

In the meantime, there will be much sporadic activity in old silver-producing mines, despite the theoretical arguments as to why most of them cannot make money. One thing in their favor is the considerable advance that has been registered in the efficiency of modern mining methods and machines. The depression has been their real friend in this respect. The rock in all these properties is just as hard as ever, but the cost of breaking and handling it has been materially reduced within recent years. Those companies that provide themselves with 1934 equipment are certain to have the best chances of success.

THE BRIDGE AGE

AMONG other designations with which historians will tag the depression period there will most likely be one denoting that it was an era of construction. True, much of this activity comes under the head of distress work, if we may borrow a term from the vocabulary of the securities markets. That is to say, a great deal of it results from the necessity of putting men to work. Nevertheless it is construction, and much of it represents the consummation of projects that have long been programmed and which are recognized as being needed.

By virtue of the financial assistance that has come from Washington, the United States is adding some fine specimens of bridges to its already notable collection. Four structures on which work is underway are of unusual size, either in their physical proportions or their cost, or both. At the top of the list is the $70,000,000 crossing of San Francisco Bay that was described in our December, 1933, issue, and next to it is the Golden Gate Bridge in the same general area. At the opposing national gateway—New York—the Tri-Borough Bridge is being thrown across the East River to link Manhattan, the Bronx, and Queens. This $44,000,000 structure was started back in the halcyon days; and the anchorages and piers for the principal suspension section had been put in place before the tightness of money forced a halt.

Not to be outdone by the East and the West, the sunny South also will have a bridge of distinction. This is being built across the Mississippi River at New Orleans within a few hundred feet of a line selected more than 40 years ago by railroad engineers who contemplated a crossing at that time. It will be 3,525 feet long and will accommodate highways, railroad tracks, and a walk for pedestrians. It will have a clearance of 135 feet, the same as that of Brooklyn Bridge.

A dozen or more bridges of lesser importance are being built. To the Delaware River Bridge between Philadelphia and Camden, N. J., are being added rapid-transit facilities that will cut the travel time between the centers of the two cities from 30 minutes to 10 minutes. A scattering of lesser structures is providing work for thousands of men, and stil other projected bridges are yet to be acted upon by Public Works Administration officials. All in all, it looks as though Uncle Sam were attempting to bridge the depression.

ATTACKING BLISTER RUST

IT has been expressed rather inelegantly but succinctly in verse that "Big bugs have little bugs on their backs to bite 'em, the little bugs have lesser bugs, and so on, *ad infinitum*."

Just so, armies have camp followers, statehouses and city halls have petty grafters, ships have barnacles, and virtually all growing things have parasites. In every instance, the unbidden tenants simply move in and exist, even wax fat, at the expense or pain of their helpless hosts. Efforts to annihilate these various animate and inanimate pests have consumed much of man's time and energy since the world began. The ouster proceedings vary with the nature of the scourge. Sometimes a vigorous application of soap and water suffices: in other cases a political revolution is required. In any event, eternal vigilance must be exercised to expel the irritant.

One of the many worth-while services that the Civilian Conservation Corps is rendering is the waging of war against blister rust on white pine trees. The regular Forest Service personnel has been carrying on this eradication work for many years, but has been hampered by its limited numbers. Now the campaign has been extended along a wider front, and the results thus far achieved have been gratifying.

The blister rust, unlike the perplexing chestnut blight, can be positively controlled and at a cost that is not excessive in the light of the benefits that accrue. Its cause is a fungus which cannot travel direct from tree to tree but which develops on Ribes plants until it reaches a stage where it can be blown to the trees. Its control consists of culling from the forests the plants which are its hosts during the transient period. Ribes plants, of which there are more than 100 species, are represented in the woods by currant and gooseberry bushes. These are more prevalent in the West than in the East, but even where they are thickest a man can clear them,on an average, from an acre a day.

A bulletin from the U. S. Department of Agriculture sets forth that during its first summer in the forests, the C.C.C. cleared 49,000,000 bushes from 574,447 acres. Other agencies added materially to this work, so that the total figures show 70,000,000 bushes stripped from 1,000,000 acres. To be effective, the eradication must be repeated periodically. In densely wooded areas the plants grow so slowly that a single clearing suffices until the pines mature. The average forest, however, must be gone through about every five years.

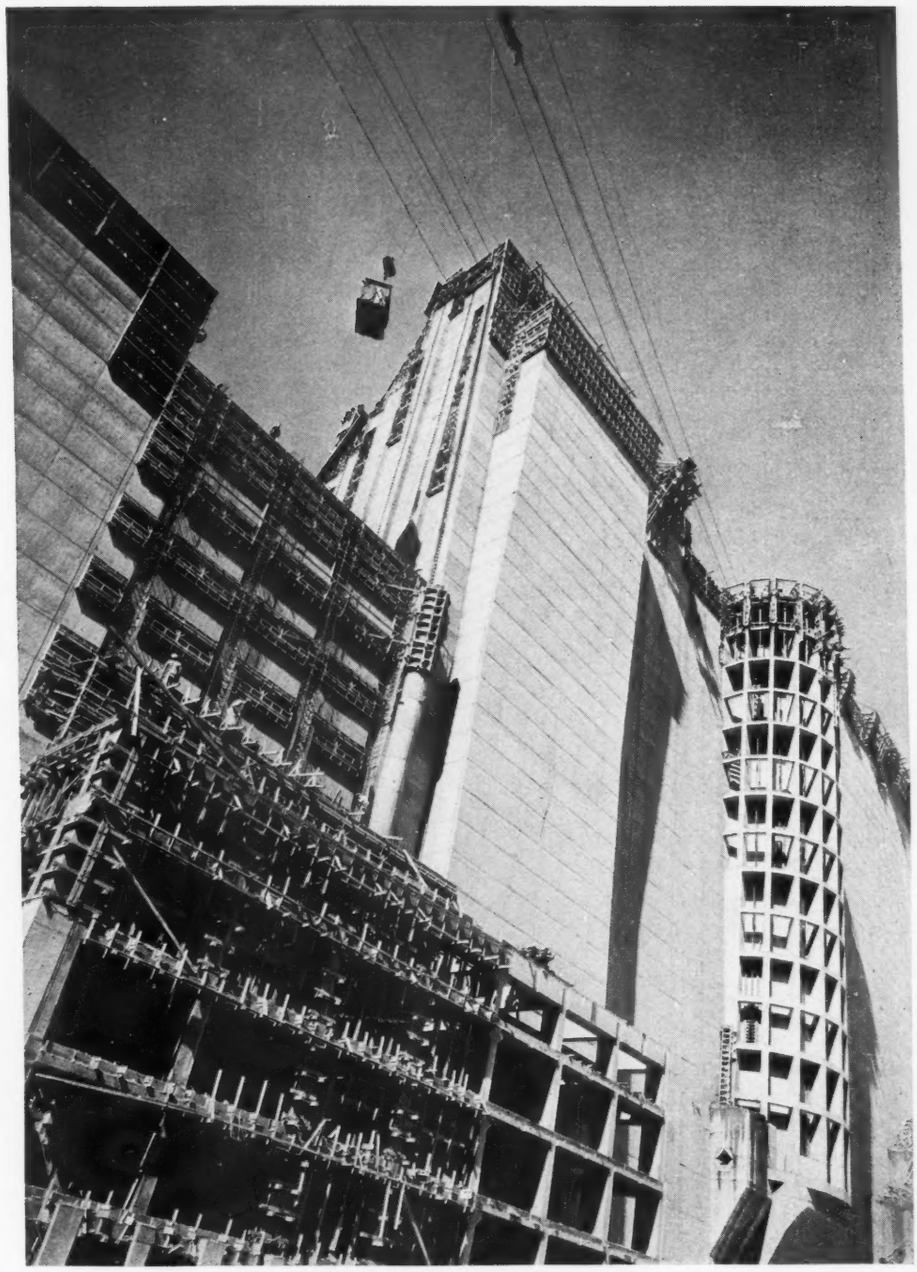
PINE CANYON DAM AT NIGHT

Weird and fantastic but beautiful is this night-time study. The castellated structure of the partly completed concrete barrier is accentuated by the play of lights and shadows. Tiny figures of men at work in the concrete forms are visible at the fringe of the curtain of light along the top of the darkened portion and about 2 inches inward from the right-hand side.

Pasadena Builds the Pine Canyon Dam

ORVILLE L. SNIDER

Photos by the author



A CLOSE VIEW

Looking up at the partly completed dam from the upstream side. The marks made by the successive 5-foot lifts of concrete are plainly discernible. Overhead a cableway bucket is being lowered with its 4-cubic-yard cargo of concrete. At the right is the outlet tower with some of its gates showing. When the dam becomes a part of the distributing system of the Metropolitan Water District, this tower will be used for releasing impounded water.

UPON moisture depends the continued growth of the Pacific southwest, especially of southern California, a desert which blossomed into a garden at the Midas touch of water and which will bloom even more abundantly as the life-giving stream is enlarged. In short, southern California's wealth, development, and beauty will be measured by the availability of inexpensive water, and of water's by-product —electricity.

Much has been written about the greatest water barricade of all time, the mighty Hoover Dam—a project envisioned back in 1902 by Arthur P. Davis, who, like many pioneers, died before his dream came true, although he did live long enough to see the vast undertaking well underway. Less has been said about the Colorado River Aqueduct, a huge lifeline of water which will stretch from the Colorado River to thirteen southern California cities comprising the Metropolitan Water District. It will be threaded nearly 250 miles across desert wastes, and approximately 90 miles of its course will be tunneled through solid rock. One noteworthy bore will be some thirteen miles long. The complete program is estimated to cost $220,000,000—nearly half again as much as the contemplated outlay for the entire Boulder Canyon Project, including the All-American Canal.

For several months past the aqueduct work has been in full swing—even the maximum temperature of 128°F. in the shade, in a region where little shade is to be had, having failed to deter the advance crews of workmen who took to the field last summer. When the job is completed several years hence, it will constitute, among other things, a mighty saga of the use of compressed air, for without this adaptable medium of power transmission it would be economically inexpedient to punch more than 90 miles of 16-foot-diameter hole through highly resistant stone.

The Colorado River Aqueduct will include as a part of its distribution system the Pine Canyon Dam, which is now nearing completion on the San Gabriel River about four miles north of Azusa, Calif. If the Hoover Dam were not projecting itself upon the horizon, the Pine Canyon structure would shape up as a fair-sized concrete dam. It rises 240 feet above the stream bed, and its roots extend 80 feet into the ground. In thickness it tapers from 277 feet at the base to 20 feet at the top. At stream

level it is 250 feet long, widening out to 756 feet along the crest. Approximately 436,000 cubic yards of concrete has gone into the dam proper, and an additional 34,000 cubic yards into the spillway and appurtenant structures. The reservoir will be four miles long, and, when filled, will impound 39,350 acre-feet of water.

The Pine Canyon Dam has been built to augment the water supply of the City of Pasadena, and the work has been carried on under contracts let by the Pasadena Water Department. It is designed to capture and to conserve the flood waters of the San Gabriel River, a stream whose recorded flow shows extremes of from 3 to 40,000 second-feet. Further upstream, the Los Angeles County Flood Control District is building San Gabriel dams Nos. 1 and 2 to provide complete flood control and regulation within the watershed. The Pine Canyon Dam will further equalize the stream flow and give additional security against floods in the lower reaches of the valley.

After Pasadena had made its plans to develop this source of water supply, the Colorado River Aqueduct program took form. As Pasadena is a party to this latter undertaking, an agreement was signed which provides that, upon the completion of the aqueduct, Pine Canyon Dam and reservoir will be taken over by the Metropolitan Water District as a part of its distribution system. Thus the waters of the San Gabriel will be made to mingle with those of the Colorado.

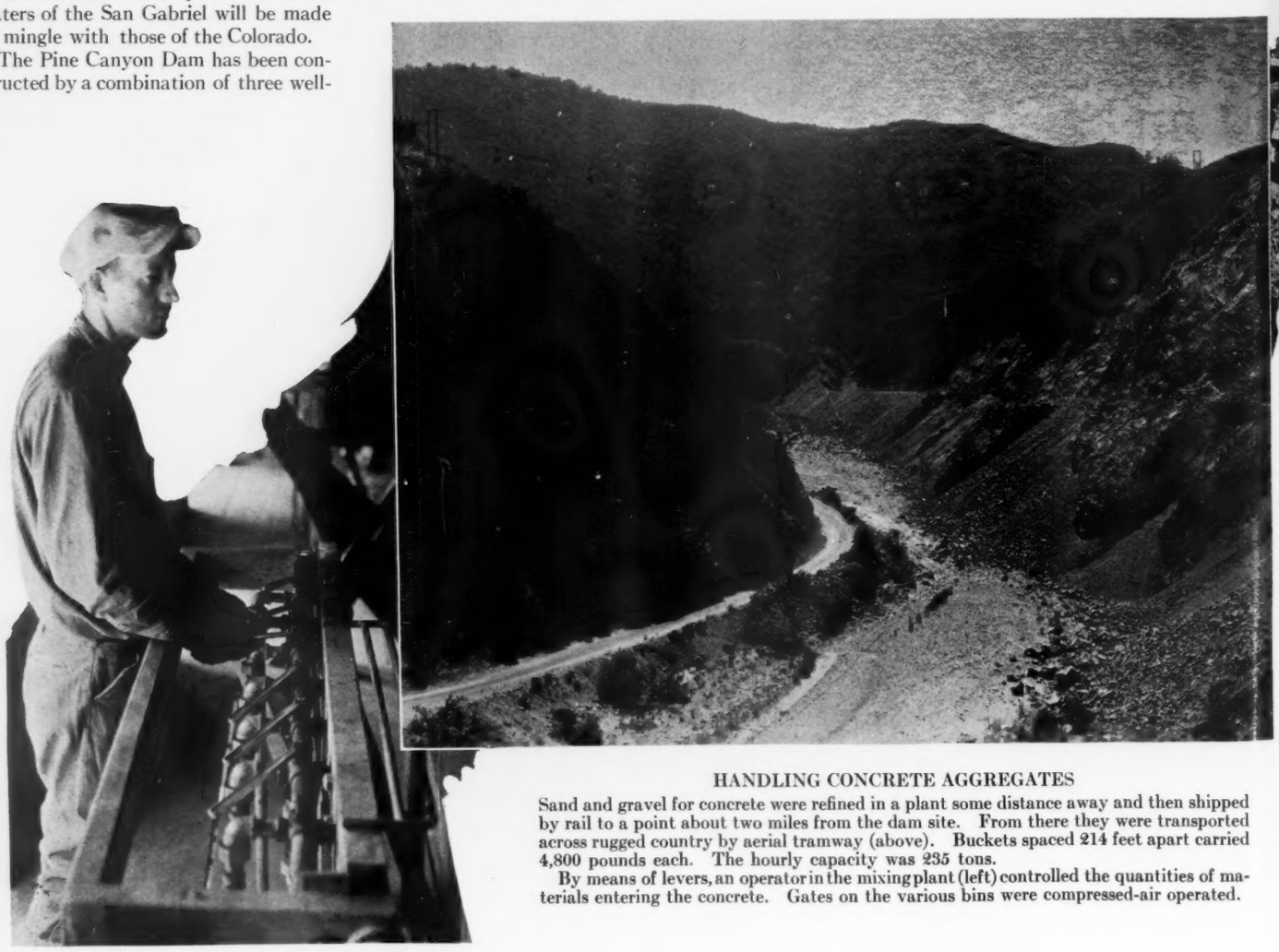
The Pine Canyon Dam has been constructed by a combination of three well-known Los Angeles contracting firms: Bent Brothers, Inc., Winston Brothers Company, and W. C. Crowell, whose contract price was $2,407,311. Work was begun in May, 1932, and is now so nearly done that the finished structure will, it is expected, be turned over to the city by February of this year.

The natural physical conditions at the dam site afforded material assistance in creating the barrier. A high ledge extending out from the west side of the canyon slope formed, in itself, a partial dam which confined the stream to a narrow channel at that point. This jutting ledge proved, upon investigation, to be essentially sound rock, and the dam was, accordingly, designed to incorporate it as the west abutment. This flank section has been grouted to increase its strength and to prevent seepage through it. Its upstream face was concreted after 190,000 cubic yards of overburden and loose rock had been cleared away and the larger projections sheared off so as to form a fairly smooth surface. An overflow spillway, having a capacity of 80,000 second-feet and provided with three gates each 18 feet high and 7 feet long, was cut through the top of this section of the dam.

Construction of the main part of the dam was watched with particular interest by engineers and contractors because it marked the first extensive use of dry-mix concrete for a structure of this nature. Concrete which is mixed and placed in the conventional manner weighs approximately 145 pounds per cubic foot. In this instance, weights up to 156.8 pounds per cubic foot were obtained by reducing the normal water content and by compacting the concrete in the forms with mechanical vibrators.

When first poured, the concrete was of such consistency that it showed practically no slump, and a person could walk over it without sinking into it. Upon being agitated, however, it became more workable and plastic. As soon as a bucket of concrete was dumped, there was inserted into it a vibrator. This was held and operated by one man, and usually two and sometimes three such tools were employed in the forms by each receiving crew. After the mixture had thus been partially compacted, a platform agitator was applied to it. This latter device transmits its vibratory impulse to the concrete through two flat metallic plates, being assisted by foot pressure applied by the two men assigned to its operation.

This procedure produced concrete of a highly uniform structure, and gave it increased density. When the forms were removed, the sides of a poured section were found to be remarkably smooth and free from openings



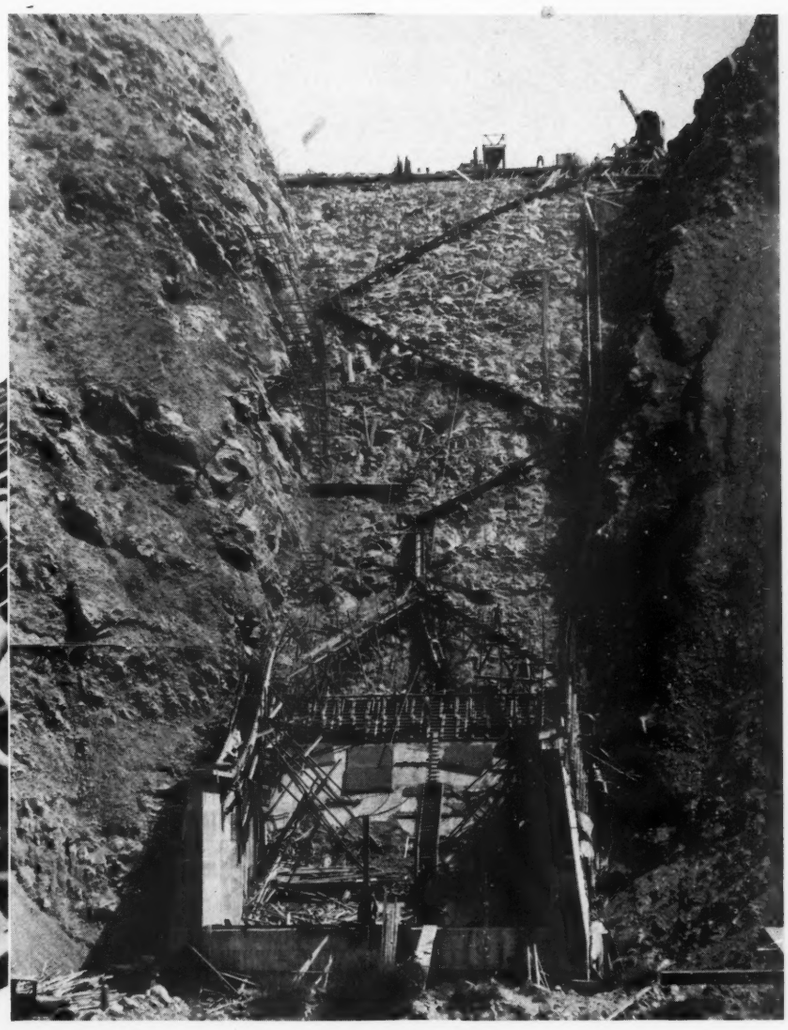
HANDLING CONCRETE AGGREGATES

Sand and gravel for concrete were refined in a plant some distance away and then shipped by rail to a point about two miles from the dam site. From there they were transported across rugged country by aerial tramway (above). Buckets spaced 214 feet apart carried 4,800 pounds each. The hourly capacity was 235 tons.

By means of levers, an operator in the mixing plant (left) controlled the quantities of materials entering the concrete. Gates on the various bins were compressed-air operated.

SPILLWAY OPERATIONS

The spillway which was cut in the rock of the west abutment is shown at the right as it appeared soon after concreting operations were started. On this phase of the work the concrete was consolidated in the forms with compressed-air vibrators (below).



of any sort. The entire surface of the dam had an even, dressed appearance, and the necessity of pointing minor defects was practically eliminated.

A special low-heat cement was used, and had the effect of slowing up the setting process and of reducing expansion and shrinkage. The heat rise accompanying the chemical reaction of setting amounted to 37°F., which is considerably lower than that for ordinary cement. Some of the studies by the U. S. Bureau of Reclamation which had a bearing on decisions in connection with the Hoover Dam concrete were applied on this job.

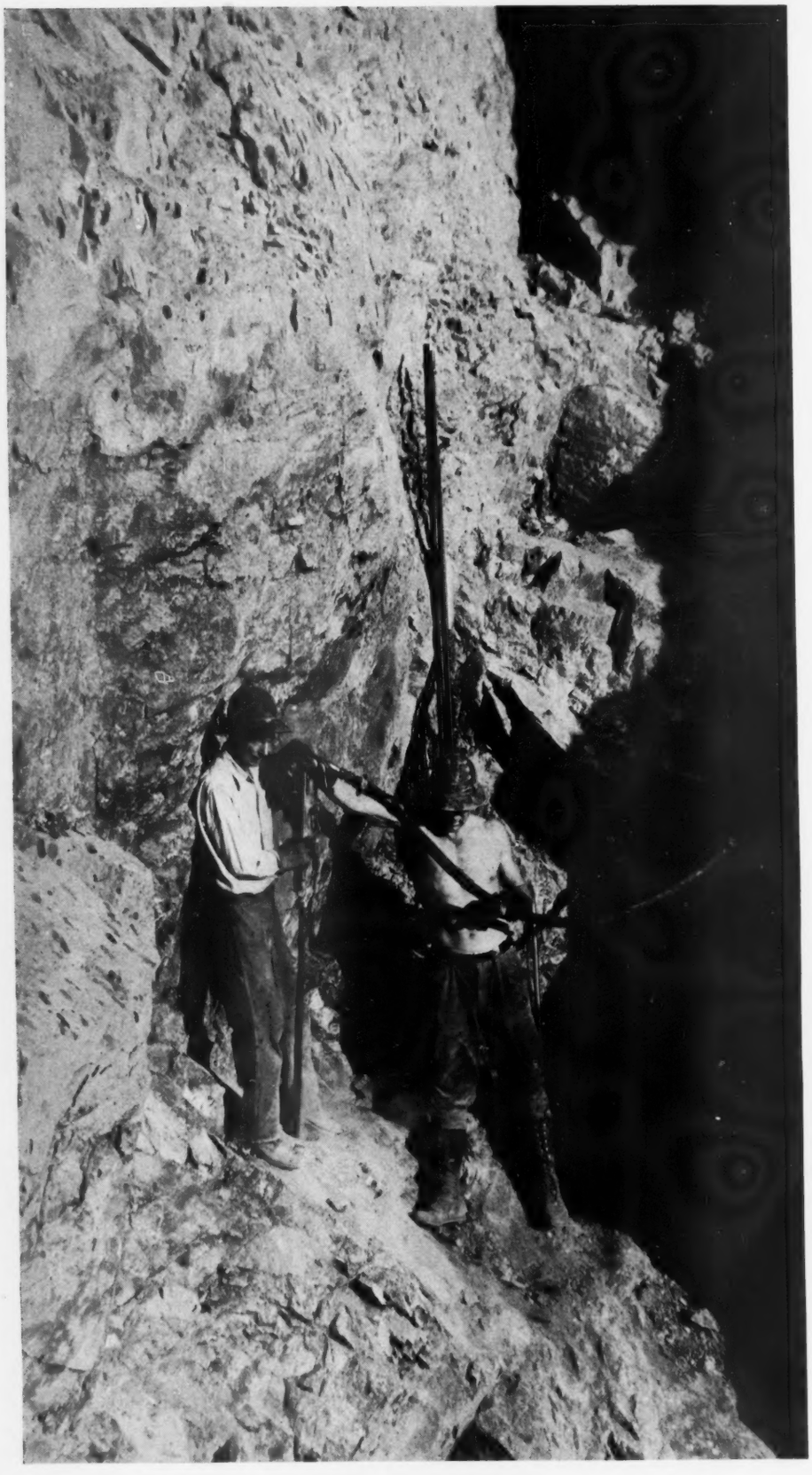
The concrete was placed by means of 4½-cubic-yard bottom-dump buckets which were transported by a 10-ton aerial cableway. This cableway had a duplex head tower and two counterweighted traveling tail towers. It was capable of moving buckets across the canyon at a speed of 1,200 feet per minute and of lowering or raising them at a speed of 300 feet per minute. The concrete was poured in alternate columns or blocks which were built up in 5-foot lifts. An interval of not less than 64 hours elapsed between the placing of successive lifts in any column.

The concrete mat on the upstream slope of the west abutment had to be poured carefully as the rock face was so steep that the concrete tended to flow unless retained by forms. An area about 600 feet long and 250 feet from top to bottom had to be covered. Concrete was laid in strips 5 feet high and about 300 feet long, and was chuted into forms from runways built along the rock slope. Three sets of forms were employed, two normally remaining on slabs already poured while the third was in use.

During the construction of the dam, the river was diverted around the working site through a box flume. To provide for the handling of a possible flood, however, a channel 10 feet wide and 10 feet high, with sides coming together in a point at the top, was left in the base of the dam. This was closed, in November, with concrete which was chuted to it through 2x2-foot chimneys which had been allowed to remain in the superstructure for this purpose. These chimneys were also subsequently filled with concrete.

Throughout its progress, the work was speeded up in various ways by the intelligent and effective use of compressed air. The main air-producing plant consisted of two Ingersoll-Rand belt-driven compressors having respective capacities of 600 and 750 cfm. Both of these machines had come to the job with imposing records of some twenty years of prior service. The larger one, originally owned by the City of Pasadena, was moved to the site in 1930 and used by the city engineers in connection with the driving of 24 exploration tunnels and the sinking of five shafts for testing the character of the rock on which the foundations of the dam were to rest. Being already available, it was incorporated in the contractors' equipment. The second unit had been in the contracting service for a score of years. Previous to this job it was used on the Pardee Dam on the Mokelumne River in northern California.

All drilling for foundations, exploration tunnels, spillway and cut-off trenches was done with "Jackhamers", the S-49 predominating. Detachable bits and solid drill steel were both used, and two drill-steel sharpeners—a No. 34 and a No. 50—were provided for reconditioning the latter. The trench for the cut-off at the upstream base of the dam was carried down-



DRILLING ONE OF THE CUT-OFFS

Keyways were cut back into the abutments on both sides of the dam site at sufficient distances to insure the safety of the structure and to make tight contacts with sound rock. The necessary drilling was done with "Jackhamers", and sometimes the footing was insecure. The picture above shows a drilling crew at work in the east cut-off.

ward from 10 to 40 feet into granite bedrock, depending upon the condition of the material as it was exposed. A concrete wall, 10 feet thick, was poured in the opening which resulted.

During the excavating for the foundations an I-R No. 25 air-operated sump pump was employed to drain collected water from shallow pockets. All told, four of these small pumps were used for a variety of purposes during the course of the work. One interesting service was the removal of clean-up water from the top of the dam as it progressed in height. The concrete for all that section of the dam downstream from a line 10 feet in from the upstream edge was poured in lifts whose upper surfaces sloped at 10° toward this line. Similarly, the concrete on the opposite side sloped toward this line, which became the low point in a depression of about 1 foot maximum depth. It was required that the last lift poured should be thoroughly cleaned with compressed air and water before the pouring of the next lift. The water used in this process collected in the depression, and one of the sump pumps was utilized to pick it up and to discharge it over the side of the dam. Another service performed by these small pumps was that of boosters in moving water from the bottoms of shafts to the regular pumps which forced it to the top.

A seam in the rock beneath the dam was followed far underground by a 150-foot inclined shaft which was later filled with concrete to obviate the possibility of leakage along the fractured plane. Muck resulting from blasting during the sinking of this shaft was removed in a bucket, which was raised and lowered by means of an old steam winch that had been converted for compressed-air operation. A Cameron air-driven pump was suspended by a cable from this winch and used to dewater the excavation. This arrangement facilitated the removal of the pump prior to blasting.

Another interesting use of compressed air was in connection with the preparation of the concrete. The nearest railroad to the dam site was two miles away, and sand and gravel were dumped at that point. There the gravel was graded in five sizes ranging from ¼ inch to 6 inches in maximum diameter. An aerial tramway was erected to transport this material to the mixing plant which had been installed on top of the west abutment overlooking the dam site. It was equipped with buckets which were 32 cubic feet in capacity and spaced at intervals of 214 feet along the cable. At the maximum speed of 500 feet per minute the tramway was capable of carrying 235 tons per hour.

Cement was trucked in bulk from four mills in southern California, dumped into a hopper, and elevated by buckets 57 feet to a storage silo. From this structure it was pumped 750 feet and at the same time elevated 302 feet by means of a Fuller-Kinyon pneumatic system which delivered it through a 5-inch line to the mixing plant. The various grades of gravel, the sand, and the cement were stored at the concrete mixing plant in eight bins which discharged their contents by gravity to either of two Blaw-Knox weigh-batchers serving two 4-cubic-yard Davis tilting mixers. The gates on

all these bins were controlled by compressed air and were opened or closed by the operation of levers at a control station. The concrete mixers were also provided with similar compressed-air controls.

Two men operated the mixing plant. Three minutes was required for mixing each 4-cubic-yard batch of concrete, exclusive of the time of charging and discharging. One of the two mixers was in continuous service for six weeks. The mixed concrete was conveyed by belts to 4½-cubic-yard bottom-dump buckets mounted on shuttle cars which spotted them under either line of the 10-ton cableway system. This cableway was capable of delivering more than 40,000 cubic yards of concrete per month when working two 8-hour shifts. The average quantity placed daily was 1,400 cubic yards, and the maximum was 2,000 cubic yards.

The upstream side of the foundation and the cut-off trench of the spillway were grouted with a mix ranging from equal parts of cement and water to 1½ parts water and 1 part cement. For this purpose, 30-foot holes were first drilled with a drifter-type rock drill and deepened to 150 feet by an air-operated diamond drill. An air-driven piston pump with rubber fittings injected the grout into the holes under a maximum pressure of 150 pounds. Except in rare instances, not more than five to ten sacks of cement could be forced into a foundation hole; but the spillway rock proved to be more seamy and in that area as many as 283 sacks were injected into one hole. The same equipment was used to grout behind the lining of the discharge tunnel leading from the spillway gate chambers, where the normal rate of injection was a sack of cement per minute. Two 3x5-foot exploratory tunnels, having respective lengths of 250 and 200 feet, were concreted by means of a Hackley pneumatic gun.

Various outlet works are provided in the dam. Water to supply Pasadena will flow through a 42-inch steel pipe installed in a tunnel in the west abutment. The first 2,600 feet of this tunnel was driven by the city forces while they were doing exploratory work. The same contractors that built the dam secured the contract to drive the remaining section of the connecting tunnel and to line it with concrete. From the tunnel a 40-inch, steel-pipe conduit will be laid to carry the water eighteen miles to Pasadena. This work is expected to cost around $750,000. The normal run-off of the river, which has to be released to satisfy prior rights, will be let through the base of the dam by means of six pipes ranging in diameter up to 96 inches. These outlets can also be used to release flood waters in case of emergency. On the upstream side of the dam there is an outlet tower containing eighteen 2x8-foot slide gates which connect with a 9-foot steel pipe extending through the dam. This tower will serve to supply the Metropolitan Water District after the Colorado River Aqueduct has been completed.

The Pine Canyon Dam was planned and built under the direction of the Pasadena Water Department, of which Samuel B. Morris is chief engineer, C. E. Pearce is designing engineer, and Ross White is construction engineer. Verne L. Peugh served as resident engineer during the construction work. Both the city and the state engineer's office retained eminent consulting engineers to pass upon the geological conditions, plans, and specifications. Lee Grider, general superintendent for Bent Brothers, was in charge of the building activities, with E. Whipple as his assistant. The undertaking gave work to between 300 and 400 men.

TWO USES OF AIR

A seam in the rock beneath the dam was followed downward 150 feet with an inclined shaft which was then filled with concrete. The central panel shows the top of the shaft with the hoisting winch, which was operated with compressed air. Small, easily handled air-operated sump pumps proved extremely useful at various stages of the work. The unit at the right is submerged in a pool of wash water which had collected on top of the concrete in the dam. With this equipment it required but a few minutes to dry up such areas preparatory to pouring another lift of concrete.

"Well, John, how's the old winze bag today?"
"Performin', Sir, performin'," grinned John.

Old Winze Bag

CHARLES DORIAN

THAT'S what they called him, Old Winze Bag—not in a deprecatory way at all. Rather was it a cognomen of merit. His name was John Peterson, and he was nearly sixty years of age; but could he play a tune on the rungs of a manway ladder with his hobnailed boots! We'll tell the underworld.

He was pale-faced from working long shifts at the bottom of the mine. His heart action was good, and he was nimble for his age from hopping sumps and climbing manways. There was gray all through his once blond hair, and plenty of wrinkles were about his eyes and mouth. He had a nose like a seafaring man that gave him a grand silhouette but looked too colorful in real life, not matching the rest of his countenance at all, for his eyes were as gray as the stubble on his chin.

In his day he had been everything from top-lander to powder monkey. But his hobby was pumps; and in these his declining years he had a formidable battery of them to look after.

And now we're coming to that funny name, which he really brought upon himself. Wherever there are pumps in a mine there are sumps, and a sump is not made by digging as one would a hole in the ground. It is made by winzing.

Winzing is performed in the same manner as sinking a shaft—that is, by first drilling holes in the rock, then blasting and mucking out the debris. It would be just as simple to say sinking a sump; but no, you've got to have the right argot in this mining game, and winzing a sump is the proper term. And a sump is a deep hole for collecting waste water to be pumped out to sumps higher up, and finally to the surface for disposal.

It was shortly after John had been put on the pumps that the name came to him. His face was, if anything, paler than usual and his nose slightly redder when he came on shift that day. The shift boss walked part way in with him and noticed that John was not at all cheerful, so he said to him: "John, you're not yourself today."

"Who the devil am I, then?" John wanted to know in his most unpleasant way.

"No, no John. Don't get huffed. I mean you're not so spry today as usual."

"And you wouldn't be either if you had bladder trouble."

"Who said you had bladder trouble? First I ever heard you mention it."

"The doc says I've got to go easy on the homebrew or the old winze bag'll need repairs."

"And what made you think that was a reference to your bladder? He might have meant your stomach," argued the boss.

"Listen, Harry, the stomach is the stope in this man's mine, and if I know my geography, the bladder's the sump. If there's any head or tail to this place you've got to agree I'm right."

"All right, John," he said as they separated. "I'll have to do some figuring myself to get the anatomy of this mine clear in my own mind."

Next time they met, John was more cheerful and the boss said to him: "Well, John, how's the old winze bag today?"

"Performin', sir, performin'," grinned John.

So they called him Old Winze Bag when they talked of him and just Winze when they talked to him.

"Hello, Winze," the shift boss said to him a long time after that, "there's a lot of water on the thirtieth level. The tram cars are up to the hubs and the trammers have to be kept in rubber boots."

"Listen, Harry, this is a big mine, ain't it?"

"Well, it's growing," agreed the boss.

"That's just it, it's growin'. It's in long pants and we're still treatin' it like a kid."

"Just what do you mean?"

"We've got just so many pumps, see? They are all in place. No spares. If they run eight hours they get sick. Some of them were here before I come. We ain't bought a new pump for three years."

"Well, you know, Winze, we're just trying to keep moving, trying to keep our heads above water in these times of depression."

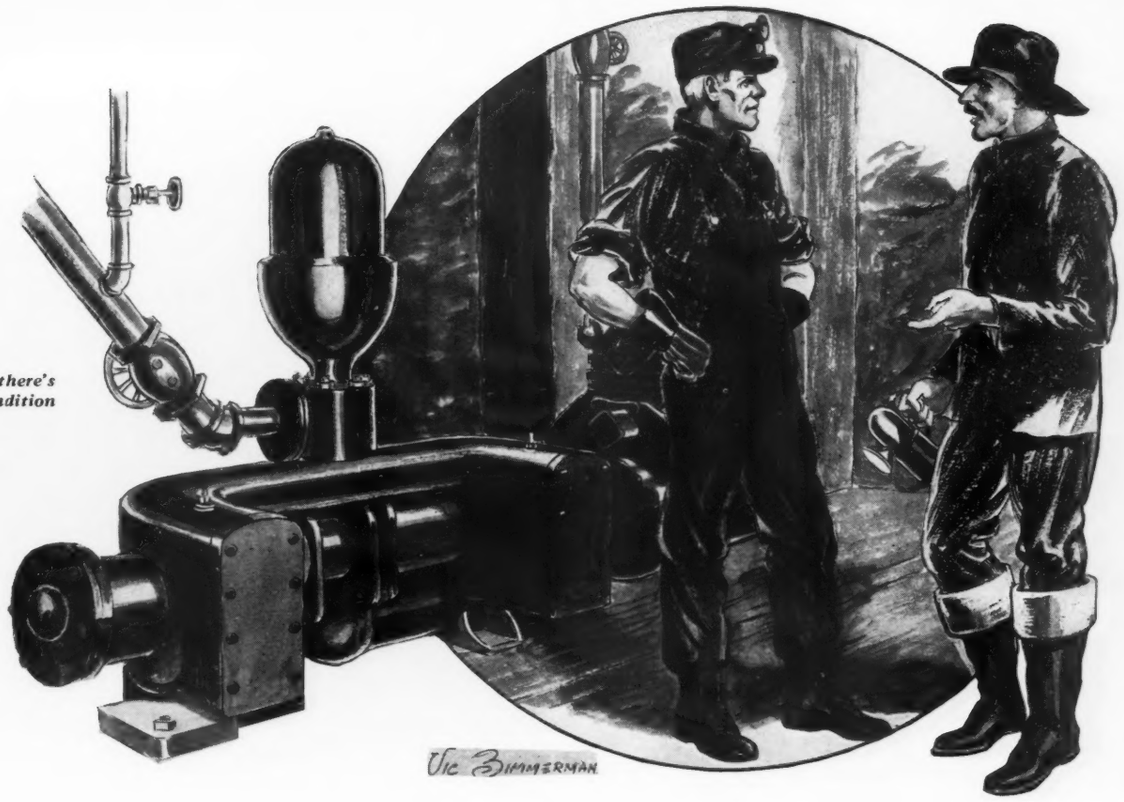
"And I'm tryin' to keep your knees above water with old worn-out equipment."

"We're keeping up the repairs," reminded the boss, "and a pump is as good as new as long as it functions."

"That's theory. They're chuggin' their hearts out. Some of these days you'll have five or six needin' new guts all at once. Then look out for a wet neck!"

"You don't mean to tell me there's not a spare pump in fit condition to replace one of these?"

"I do just that. If there was a pump to take down to the thirtieth, that one-lunger down there'd go to the surface so fast that they'd



"You don't mean to tell me there's not a spare pump in fit condition to replace one of these?"

think it had come by wireless!"

"How long has this been going on?" The boss tried to be stern.

"How long is it since you began dolin' out rubber boots?"

"Only yesterday," said the boss.

"Well, there's been signs of it for a week. And it's only showin' up bad now because the new sump they winzed a month ago is overflowed and no pump installed yet."

"That's serious. Why didn't you mention it before?"

"You been talkin' economy and depression so much I thought you meant to let the mine fill up to save pumps," drawled Old Winze Bag.

"You old reprobate," laughed the boss, "I'll go on up and see the master mechanic and find out what we can do about pumps."

"Tell him," John advised in parting, "to look over that pile of old drill steel and those old reels of wire rope, maybe he can make a couple o' pumps out of them."

John went down to the thirtieth level to start work, chuckling to himself. It was wet all right, and he sloshed over to where the pump lay silent. He turned the air valve, and the pistons began to chug courageously.

"When the water's knee deep they'll probably learn that the depression's been over six months," John mused.

The master mechanic produced figures to the shift boss to prove that there were enough pumps in the service to keep the mine dry by operating them one full shift of eight hours only one-third of the time. If they were not performing that service there was something wrong with the pump man. The shift boss in charge of the levels from the twenty-sixth to the thirtieth could not speak for the other levels, so he took the matter up with the mine captain.

The mine captain secured a blue print showing the location of all pumps, and he systematically went from level to level to see if they were working. He discovered that every one was pumping vigorously. He sought out Old Winze Bag to know why the mine was wet on the thirtieth.

"Shortage of mops," answered John, "and the men have stopped drinkin'."

"Seriously, John," said the captain sternly, "I feel like giving you a two weeks' holiday and putting somebody on these pumps who will get efficiency out of them."

"Efficiency, is it?" grunted Old Winze Bag. "If your heart didn't get any more sleep than those pumps you'd have been measured for a wooden suit long ago."

"Those pumps are designed for continuous service," argued the captain, "yet they operate only eight hours in the twenty-four and the mine's as wet as the Mississippi in flood."

"Well, I'm from Missouri," retorted Old Winze Bag, "I'll take the two weeks, captain. I need a rest, anyway."

"It will do your tongue good," scolded the captain.

Captain Morgan felt the full force of his responsibility. Here was a fine dilemma. A wet mine to celebrate his twenty-fifth year as captain! And all because Old Winze Bag had had his own way with the pumps. He sought out the shift boss in charge of the thirtieth level.

"What's old John Peterson been putting over on you, Harry?" he demanded.

"Eh? Nothing that I know of. Why?"

"Do you know that we'll be paying out more for rubber boots in a couple of weeks than would put two good pumps on this level?"

"Well, I suggested a week ago putting a pump at the new sump and running them both two shifts till we get dried up," hinted Harry Swan. "Old Winze Bag is doing all he can."

"Was doing, perhaps," retorted the captain. "He's taking an enforced vacation for a couple of weeks. I've a suspicion that he has the pipe line fixed up to suit his own nefarious ends."

"Nefarious! Old Winze Bag nefarious? He doesn't even know the meaning of the word," objected the shift boss.

"Do you?" snapped the captain.

"Eh? Oh, sure—you mean hilarious don't you?"

"Now, listen, Swan. We've spent a devil of a lot of money on upkeep of these pumps. Nobody is denying that most of them have been here since the devil pumped Adam about orchard conditions away back in history, but that's neither here nor there. We've got two pumps on each level which should handle the seepage and deliver to the big triplex pumps that shoot to the surface. We've been taking pumps up to the shop and fixing them in a hurry to get them back into service without interrupting the flow. And you've got to admit we have handled them satisfactorily until now. Old Winze Peterson knows pumps, and he is perfectly right about our needing half a dozen spares if for nothing else than to save the cost of repairs and the frequent handling of pumps up and down. But we are told not to initiate any new expenditures—to carry on during these hard times the best way we can. The management does not consider a few pistons, or impellers, or glands, or bushings as very much, no matter how often we order them or how many we order. But put in an order for a new piece of equipment, such as a

"The water's over their boot tops!"

complete pump, and the order dies a-borning. And to suggest working a double shift, entailing that much extra labor even for one man, meets with the same ruthless response. Now I believe Old Winze Peterson has been trying to force an issue. New pumps would make his job easier, so I suspect that he has been pumping out of the old sump into the new one right on this level instead of shooting the water up to the main pump sump."

"Oh, Mr. Morgan, cap'n, Old Winze Bag wouldn't do that!"

"No? Well, let's assume that he would, and do some investigating on that pipe line to see how he's by-passing that water. It is up to you."

So saying, the captain left the shift boss to worry about the solution of the dewatering problem on the thirtieth level, while he went off whistling softly to himself.

Two days later the superintendent called him in: "What's old John Peterson doing?" he asked. "I saw him come leaping over the hills an hour ago and waited for him. I asked him what he was doing out there, and the only answer I got was that he was on furlough. What the devil does he mean?"

"He's on a holiday," explained Morgan. "We've been having trouble with the pumps and I thought it would be a good idea to put another man on them for a while to see what the trouble actually is."

"And in the meantime the trammers are threatening to quit work on the thirtieth level because they haven't bathing suits!" The sarcasm was leaden.

"Conditions are bad, I'll admit. We should run the pumps three shifts for a few days. It may mean a breakdown of several pumps, though, and we have no spares, and it will mean two more men."

"Get Peterson back till we hear what he has to say. He has handled the pumps long enough to know what we need," advised the superintendent, with signs of rising temper.

It took two hours to round up Old Winze Bag. He was finally located half a mile back of the mine hopping from one bowlder to another like a sprite in a spring dance. He came when called, with a grin reaching from ear to ear. He said nothing to his guide, and kept his silence until the superintendent spoke to him: "How many new pumps do we need in this mine?" The question was shot straight at him, but he never winced.

"About twenty-four—a whole flock, anyway," he modified.

"Are you crazy?" crabbed the captain.

"Six new pumps would have been ample a week ago," drawled the disgraced one, "but since I've been off - - - - - -."

"Oh, of course, without your efficient handling it takes four times as many," mocked the captain.

"In a way o' speakin', yes," grinned Old Winze Bag. "I've suspected for some little time that conditions were not what they used to be. We need either bigger pumps or more of 'em."

"To what conditions do you refer?" asked the superintendent, holding himself in with an effort.

"Do you think," exploded Old Winze Bag, "that I been out there makin' a monkey out o' myself climbin' rocks because there's no trees to climb just for the fun o' seein' how grand nature is? I been out there doin' what your engineers would 've been doin' if they wasn't all laid off."

"What do you mean," snapped the superintendent. "Out with it."

"Sort o' studyin' the topography." Old Winze Bag was apparently in no hurry.

At that juncture, however, Harry Swan came in.

"The men have all come up out of the thirtieth level," he announced, dourly. "The water is over their boot tops."

"And it'll be over their heads afore night," cut in Old Winze Bag. "You may think I'm crazy, but there's a crack six feet wide and six hundred feet long back there where I was makin' observations before I was disturbed. Lake Ona is gradually seeping into that long chasm. It is a matter of a few days when the whole lake—of course it's only a small one, about two million gallons I'd say—will come into this mine via the thirtieth level."

"Shut up and get out of here, all of you. Do something to stop that rush of water. I'll get the general manager on the 'phone and order the pumps."

On the way down in the cage Harry Swan said to Old Winze Bag: "Say, Winze, what's the meaning of nefarious?"

"Why?" asked the old man, cautiously.

"Well, I mean, what could we do down there to that pipe line, for instance, for our own nefarious ends?"

"Get a couple o' boats," advised Old Winze Bag. "There'll be more seafarin' than pumpin' for a few days, I'm thinkin'."

SOUTH PORTAL

Most of the operations were conducted from this end, where shops, camp, etc., were located. Shown below is a section of the completed tunnel. Ventilating pipes are visible at the left side.

Railway-Tunnel Driving in Norway

B. HOLMSEN

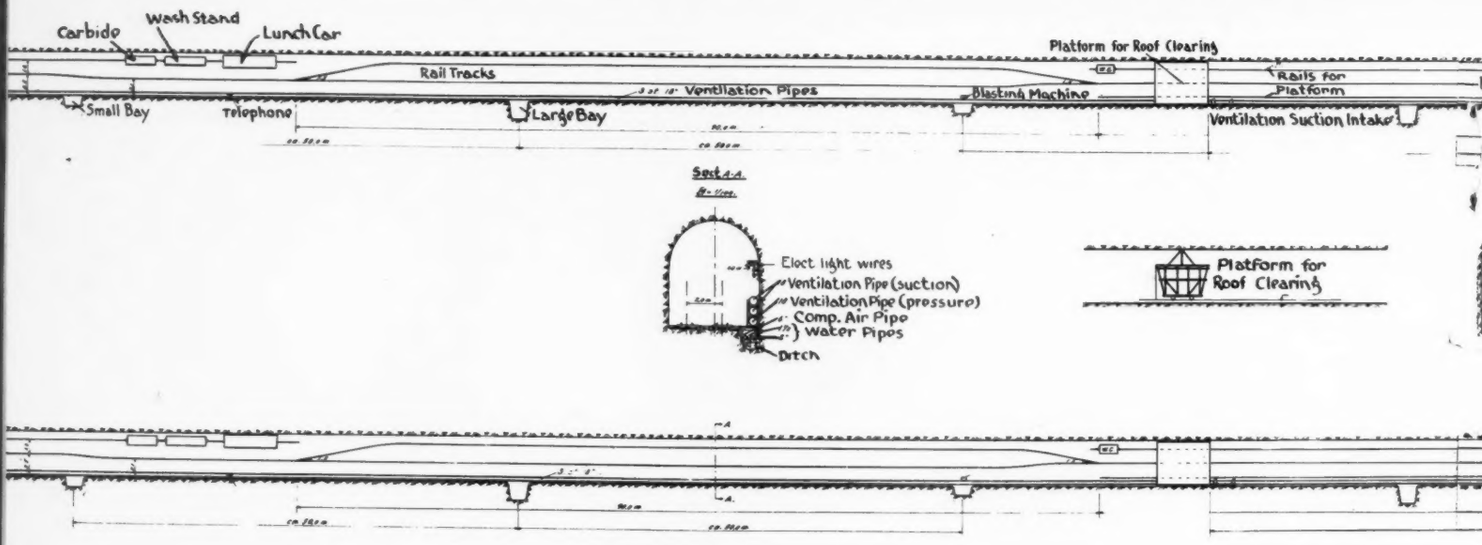
THE river and coastal topography of Norway is of unusual and distinctive character. It is a predominantly mountainous country with long and deep fiords cutting into the land and with valleys which are generally deep and narrow except in the southeastern part, but even this is of a hilly nature. Norway has an over-all length of 1,100 miles, but varies in width from 260 down to 5 miles, the average being about 60 miles. Some of the fiords penetrate the land for 70 to 100 miles. The population of the country is less than 3,000,000, or only about 21 persons to the square mile.

Railway building cannot be a prosperous undertaking under physical conditions such as these; and with few exceptions the railroads are, accordingly, all built by the government. The largest cities are now linked by rails, but there are still two main lines missing to complete the general scheme. These are the Northern Main Line from Trondheim and points northward, and the South Western Main Line via Kristiansand to Stavanger. Both are under construction. The original plan called for a number of other lines; but, since the introduction of large motor omnibuses and trucks, the emphasis has been on highways, at a sacrifice to the railroads.

Owing to the peculiar conditions mentioned, railway building in Norway differs in many respects from that in other countries where railroads are operated at a profit. Time of completion is not of such great importance, but low construction cost is a controlling factor. For this reason, and also to lessen existing unemployment, hand labor is much used. Even so, speed of building has to be considered in the case of the longer tunnels; and hand-labor methods of driving them, while inexpensive, slow up the work to an extent that is undesirable. Time is a particularly important factor on the South Western Line between Kristiansand and Stavanger. One stretch of about 60 miles of this projected route consists of approximately 24 miles of tunnels. The two longest of these are, respectively, about five and six miles, and they are separated only by a narrow valley. With an eye to working out effective methods of driving these bores, the Railways Main Direction decided to experiment with modern tunneling procedures in the case of the Grong Tunnel on the Northern Line. The object was to determine the rate at which both speed of construction and low cost could best be balanced. From these two standpoints, the methods employed and the results obtained have been very satisfactory, and it is of them that this article will treat.

The Grong or Tömmeras Tunnel is 8,300 feet long, 16.5 feet wide, 19.5 feet high at the center, and has a cross section of 295 square feet. Its course is straight except in the middle portion, where there is a curve 1,750 feet long and having a radius of 6,600 feet. Four-fifths of its length was driven from the south portal, where plant and equipment structures were situated. The track ascends from either end on a grade which varies from 2.5 per cent on the south slope to 5 per cent on the north slope. The high point is about one-third of the way in from the south portal, which is 53 feet higher than the north portal. From south to north, the line runs through approximately equal stretches of granitic gneiss, mica schist, and hornblende schist.

Preliminary operations were started in January, 1927, but for various reasons the work was interrupted at times and once stopped entirely for seven months. The



PLAN OF OPERATIONS IN THE TUNNEL AS THEY WERE CONDUCT

The upper line shows the arrangement of structures for drilling in the bottom heading and loading from the platforms and the ditch.

tunnel was holed through on September 10, 1931, and was completed on July 2, 1932.

The original plan was to advance a bottom heading, 10 feet wide and 8 feet high, in the center and to enlarge this to full width. The remaining top section of 163 square feet face was then to be taken out in two horizontal "slices" by blasting the material down on to portable loading platforms. The purpose of this procedure was to secure as many working faces as possible. Later a modification of the plan called for driving the initial bottom heading on one side of the tunnel line, representing half the ultimate width. At the same time, the height was increased to 10 feet. Finally it was found that much time could be saved in setting up for drilling and for scraper loading by concentrating operations; and, in the interest of economy, the bottom heading was increased to full tunnel width, thereby providing a working face 16.5 feet wide and 10 feet high. After this was excavated, there remained a face having an area of 130 square feet, and this was removed in two slices, as before. This method was adopted in June, 1928, and was followed from that time on until the work was finished.

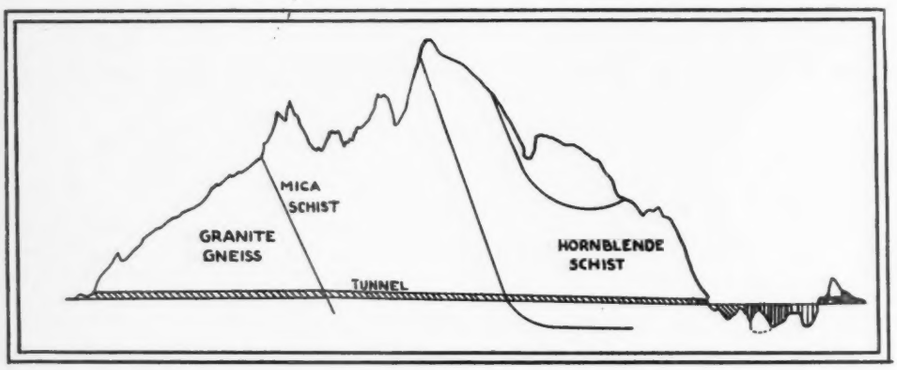
The platforms on to which the top material was blasted were fitted with chute gates made up of removable boards, and by their means the muck was loaded by gravity into cars run under them. Using this equipment, a blast of from 60 to 70 tons was loaded in 3½ hours or less, depending upon the amount of secondary drilling of large bowlders that had to be done. The platforms were mounted on wheels and moved along tracks by a locomotive. They were equipped with a large number of heavy springs which served as shock absorbers. Two platforms, one for each slice, were originally employed, and one preceded the other by about 500 feet.

As the tunnel progressed, the time required to withdraw smoke increased to such an extent that operations were hampered, particularly on the outer or rearward platform. To alleviate this difficulty it was decided to concentrate work also on the top section, with the result that the two top slices were excavated in quick succession and blasted down upon the same platform. Likewise, the distance the bottom heading was carried ahead of the top section was reduced from 650 feet to 400 feet, the shortest practicable stretch in which to provide the necessary facilities for switching cars. This change in procedure was adopted in October of 1930, and was followed from that time on until the Grong Tunnel was completed.

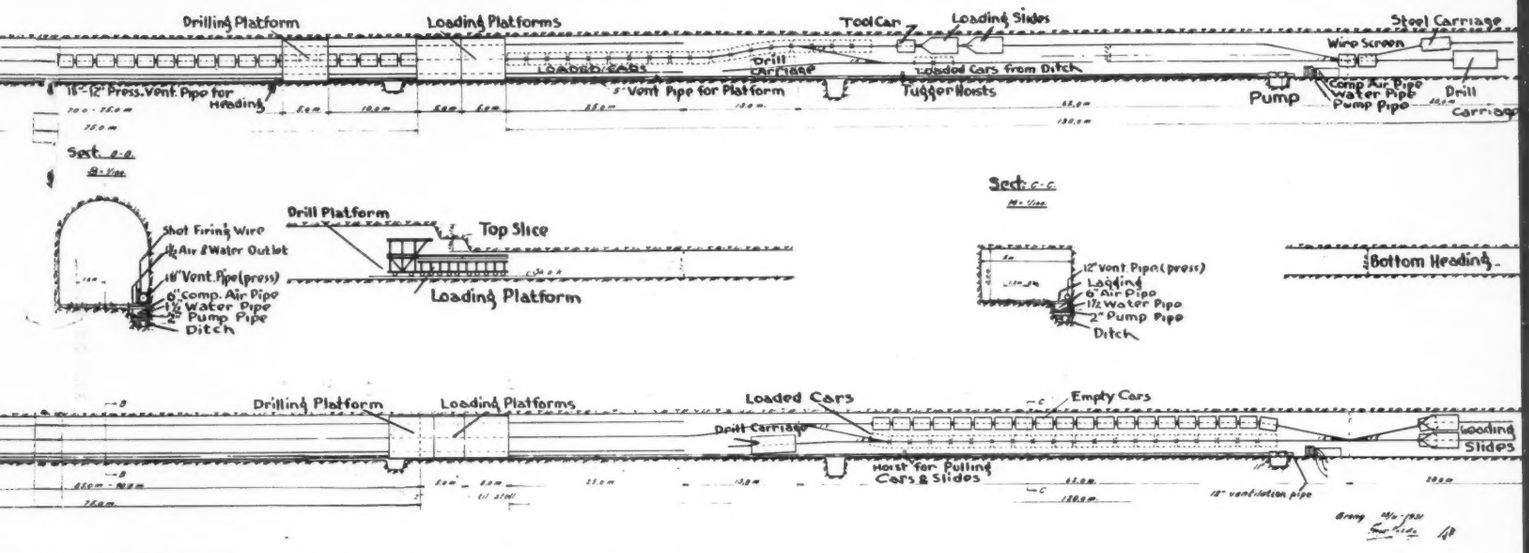
The lower slice was drilled from the loading platform, the upper slice from a special drill platform having a stationary set-up. This latter structure was stationed directly back of the loading platform. It consisted of two levels, the lower of which was continuous with the top of the loading platform, and was provided with water and compressed-air manifolds for supplying the drills both on the loading platform and on its own upper level. Two drifter drills were used at each of these locations. The manifolds were connected by hoses to the hollow shafts of reels on which were wound the hoses employed for making connections with the main water and air lines extending into the tunnel. The special drill platform also carried spare drills, drill steel, columns, and various other necessary items of equipment. The general features of the platforms and the manner in which they were used are shown in some of the accompanying illustrations.

The drilling round for the lower slice consisted of twelve holes and for the top slice of eight holes. These were from 8 to 10 feet deep and took about two hours to drill. From 20 to 25 pounds of low-grade ammonia-base explosive sufficed for loading all twenty holes. Firing was done with ordinary fuse and caps, and the drill platform was moved back 40 to 50 feet from the loading platform during blasting. Peripheral holes were loaded very lightly in order to insure a solid roof and to obtain a true tunnel section. Except for a distance of 130 feet, the rock stood so well that no lining was necessary.

The bottom heading was driven with the aid of a drill carriage on which were mounted six drifter drills in horizontal position. Facilities for supplying compressed air and water



LONGITUDINAL SECTION OF GRONG TUNNEL



NDUCTED AFTER EACH WEEKLY MOVE FORWARD OF THE EQUIPMENT.

The lower line indicates the positions of the equipment for drilling on the platforms and in the ditch and loading in the bottom heading.

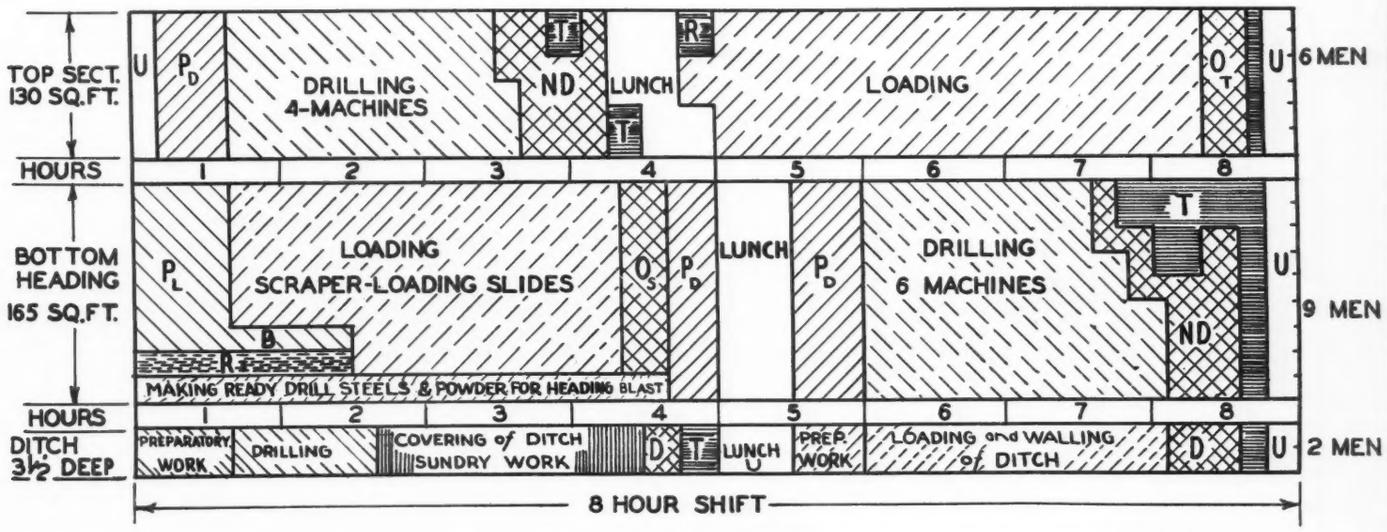
were similar to those on the drill platform previously described. The drills were mounted on columns which could be moved in a horizontal plane so as to adjust the set-up to the requisite distance from the drilling face. They were also arranged so that during moving they could be swung back over the carriage by means of a toothed sector. Details are illustrated.

Various arrangements of drill holes were employed for blasting the bottom heading, the round being changed with the nature of the ground and with the various set-ups which served prior to the standardization of the section and the construction of the drill carriage. The rounds which were most used are illustrated. The most satisfactory of these (No. 12) consisted of 32 holes: six cut holes 9½ feet deep; twelve relievers 8½ feet deep; and fourteen profile holes 8 feet deep. The total drilling required was about 250 feet, which was done with six drills in about two hours, or an average of approximately 21 feet per hour per drill.

The cut holes were loaded with special gelatine dynamite containing 70 per cent nitroglycerin, and the other holes with gelatine dynamite containing 60 per cent nitroglycerin. About 160 pounds of explosive was used for the complete round, and of this the cut holes received about 40 pounds. Firing was done electrically with instantaneous detonators for the cut holes and six delays for the others. The bottom holes were the last ones shot. Current was drawn from a storage-battery locomotive, and the circuit was closed with an ordinary knife switch located about 800 feet from the face. The advance made with each round ranged from 6 to 7 feet.

It should be mentioned that the upkeep cost of the drills was reduced very considerably with the introduction of the drill carriage. Water for the drills was accumulated in a pit and then transferred to a tank from which it was forced by air under pressure to the points of use.

Loading of muck in the bottom heading was done with two scraper slides, and from three to four scraper loads filled a car of 2.2 tons capacity. From 100 to 110 tons of material was shot down with each round, and this was generally loaded within three hours. Cars were shifted by means of a "Little Tugger" hoist. To limit the scattering of the rock and

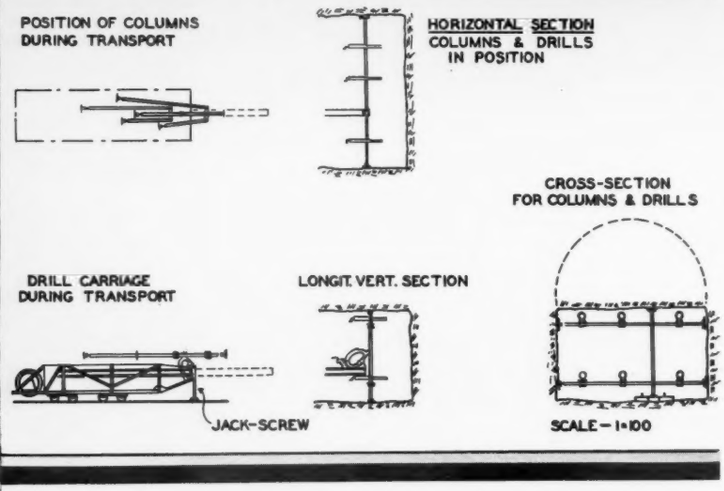


CYCLE OF OPERATIONS

PD-PL preparing for drilling and blasting, respectively; B, placing bolts for scraper loading; ND, dismantling and removing drilling equipment; OT, clearing and moving platform in position for blasting; OS, clearing and moving back loading slides; D, placing protection to prevent scattering of rock; T, loading and firing; R, barring down loose rock after blasting; and U, clearing after blast.

OPERATIONS IN THE BOTTOM HEADING

The bottom heading was advanced variously before experiments proved that the most effective method was to drive it full width, 16.5 feet, and 10 feet high. Drilling was done with the aid of a carriage with six drifter drills mounted in two horizontal rows of three each. The arrangement of the drills was such that they could be swung back over the carriage during its moving. Loading of spoils was done with two scraper slides. The accompanying illustrations show how operations in this heading were conducted.


POSITION OF COLUMNS DURING TRANSPORT
HORIZONTAL SECTION COLUMNS & DRILLS IN POSITION
CROSS-SECTION FOR COLUMNS & DRILLS
DRILL CARRIAGE DURING TRANSPORT
LONGIT. VERT. SECTION
JACK-SCREW
SCALE - 1:100

to protect the loading slides, a wire net was suspended across the tunnel about 60 or 70 feet from the face during blasting. Light for the operations was supplied by a generator and storage battery powered by air-operated Ingersoll-Rand No. 7 grinders mounted on the slides. A water ditch at one side of the tunnel was maintained up to within about 80 feet of the breast. This was drilled with an I-R DCRW-23 "Jackhamer." The tracks, the wire net, and the "Little Tugger" hoist were moved every week-end. An accompanying sketch shows the arrangement just after such a shift had been made.

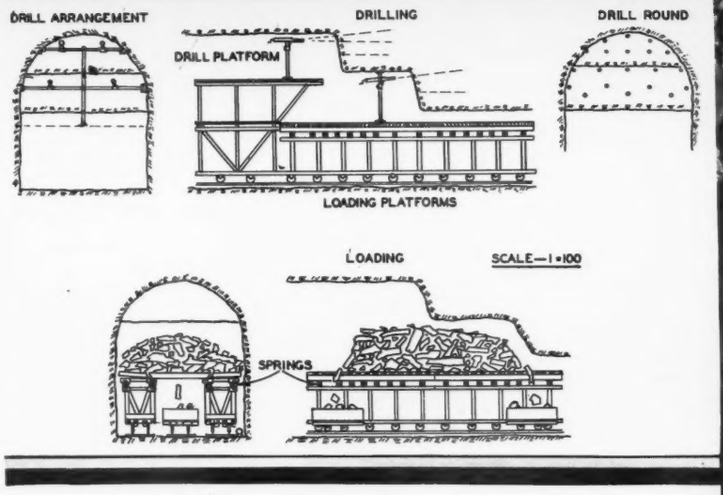
Compressed air was supplied by two electrically driven Ingersoll-Rand compressors having a combined output of about 880 cfm., and by an Atlas compressor of 180 cfm. capacity. A constant pressure of 100 pounds per square inch was maintained by using three large air receivers connected in series. Air was piped to the working faces by a 6-inch line which had 2-inch take-offs every 160 feet. Water traps were placed at suitable intervals. This line and a 1½-inch water line were placed in the ditch to protect them from blasting. Connections from these lines to the drill rigs were made with 2-inch flexible hoses in the manner previously explained.

Ingersoll-Rand drifter drills were used at all faces, S-70's at the bottom heading and N-72's on the platforms from which the overhead sections were drilled. Hollow, round drill steel of 1¼-inch section and with Leyner type shanks was employed with all drifters. The "Jackhamer" steel was ⅞-inch hollow hexagon with 3¼-inch collared shanks for ordinary work and, occasionally, 1-inch hexagon with plain shanks for stoper work. Four-point bits served all the self-rotated drills. Some work was done with hand-rotated stopers, and for this 6-point bits were utilized. Drifter holes were started with steels 55 inches long and with 2¼-inch bits. The feed provided for a change of steels every 30 inches, and holes were finished with lengths up to 13 feet and with 1¾-inch bits.

The blacksmith shop contained a No. 50 sharpener, a No. 25 oil furnace, and a No. 8 pedestal grinder. A special carriage was employed for transporting the drill steel to and from working points. Ninety-five bits were sharpened and five shanks reconditioned for every meter (3.28 feet) of tunnel advance. The total steel consumption per meter was 21 pounds, of which 30 per cent represented wear, 37 per cent breakage, and 33 per cent short steel (below 36 inches). About 0.55 pound of oil was required per bit and shank, including the amount that was used for tempering.

Transportation in the tunnel was handled by two storage-battery locomotives guaranteed to pull 70 tons on a 2.5 per cent grade and capable of traveling 560 ton-miles on a 5 per cent grade with each charging of 73 amperes of 220-volt current. The ordinary load hauled consisted of eighteen cars, or approximately 50 tons.

Three Sirocco fans, of 3,530 cfm. capacity each, were used for ventilating the tunnel. Two served as suction units and the third as



DRILLING AND LOADING THE UPPER SLICES

After the bottom heading had been driven a suitable distance ahead, the overlying section, 16.5 feet wide and 9.5 feet high, was removed in two slices. Drilling of the lower slice was done from the top of a movable platform, which also received the muck blasted down from both slices. The upper slice was drilled from a platform which was run up behind the loading platform. The accompanying photographs and drawings illustrate these phases of the operations.

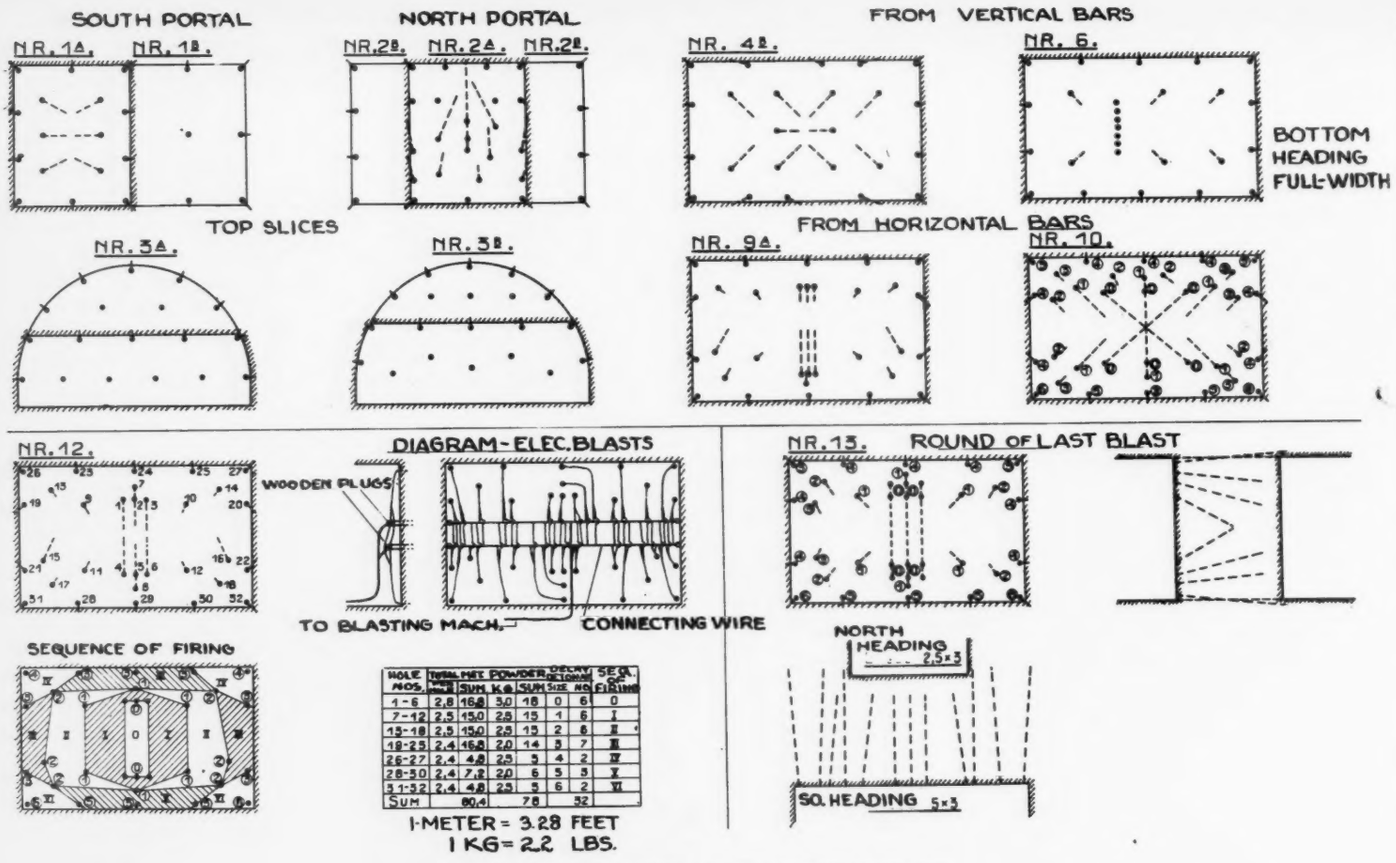
blower. Eighteen-inch pipe was installed. A platform used for trimming and inspecting the roof, and stationed about 250 feet back of the loading platform, was covered with canvas to stop the progress of the smoke. The suction intakes were placed in this "smoke chamber"; and, because of the slight vacuum created in the forward part of the tunnel, the portions outside this structure were thus kept perfectly clear. A 12-inch pressure line, which terminated in a 100-foot length of canvas, carried fresh air to the working faces, and a 6-inch take-off supplied the loading platform. This system worked so well that operations could be resumed at the bottom heading fifteen or twenty minutes after a blast and in the top section as soon as ten minutes thereafter.

Changes of shifts took place on the portal side of the smoke chamber, about 1,000 feet back from the face. At that point was stationed a portable lunch car which was heated with electricity and ventilated with air taken from the main header through a hose. A carbide and washstand car was attached to the lunch car. First-aid appliances and a telephone also were available there.

Work was carried on in two shifts, and the total tunnel crew numbered 52, including repairmen and supervisors. The drilling and loading crew consisted of six men on the platforms, nine at the bottom heading, and two in the ditch. For half the shift, drilling was carried on at the top-section faces and in the ditch while muck was being loaded at the bottom heading. These operations were reversed during the remainder of the shift.

The average advance per shift during the last stage of driving was 7 feet for the full tunnel section, and the best progress per shift was 8½ feet. During the period of experimentation, the total working time required was reduced from 34.5 to 19 man-hours. Because of the variation in the rock and the different types of explosive tried out, the consumption of dynamite ranged from 20 to 36 pounds per foot of full tunnel section. Exact data were taken of the last 90 blasts in order that the figures might be compared with those obtained during some German investigations of blasting made in 1930 by Doctor Becker. The dynamite consumption per cubic foot of rock was a little higher at Grong but, on the other hand, the advance per blast was considerably greater. The footage drilled per cubic foot of rock was slightly less at Grong, but both the drilling efficiency and the blasting efficiency were better.

In the following table is a calculation of costs of railway tunnels of various lengths, based upon the results obtained at Grong. This estimate was made up with particular reference to the projected tunnels on the South Western Main Line. The average advance per shift is assumed to be seven feet; the number of shifts per week, eleven on a 2-shift-day basis and seventeen on a 3-shift-day basis; and the working year, 46 weeks. Prices are based on the 1930 level and on gold values with the Norwegian krone at 3.75 to the dollar. Wages are assumed to average 50 cents per hour, and the dynamite con-



HOLE NOS.	TOTAL NET POWDER SUM KG	SUM	DELAY SECTIONS SIZE	NO.	SEQ. OF FIRING
1-6	2.8 16.8	3.0	18	0	6	0
7-12	2.5 15.0	2.5	15	1	6	I
13-18	2.5 15.0	2.5	15	2	6	II
19-25	2.4 16.8	2.0	14	3	7	III
26-27	2.4 4.8	2.5	5	4	2	IV
28-30	2.4 7.2	2.0	6	5	3	V
31-32	2.4 4.8	2.5	5	6	2	VI
SUM	80.4		78		32	

DETAILS OF DRILLING AND BLASTING SCHEMES

Some of the various drilling plans, which were tried out before the procedure in the bottom heading was standardized, are shown here. In Nos. 4B and 6, four machines, each mounted on a vertical bar, drilled 24 and 27 holes respectively. Nos. 9A and 10, having 31 and 36 holes respectively, were drilled with six machines mounted on horizontal bars. An average advance of 8½ feet to the round was made with the No. 10 plan, but under it the rock was scattered so badly that loading operations were handicapped. Nos. 6 and 9A produced smaller footages, but the rock broke more conveniently for loading. The most satisfactory of the different schemes was that shown in No. 12. Details of the blasting of this drill round are also shown, as well as a table giving the amount of powder that was used per hole.

sumption 34 pounds per linear foot of tunnel. These figures indicate a total cost per foot of completed tunnel ranging from $56.50 for a length of 1.25 miles down to $48.50 for 3.1 miles. No provision has been made for lining, and it is expected that none will have to be placed in the South Western tunnels by reason of the nature of the rock through which they are being driven.

The Grong Tunnel is located in the district in charge of C. H. Hoelfeldt-Lund, chief engineer of the southern section of the Northern Main Line, and it was mainly through his efforts that this experiment with modern tunnel-driving equipment was decided upon and brought to a successful conclusion. Full credit should also be given to the resident engineers in charge of the operations—H. C. Engen and I. J. Roseg, who took up the work after the former's departure.

During the development of the loading platforms and slides and the drill carriage, patents were applied for in the United States and in most European countries. These patents are now held by A. S. Holeng, Trondheim. In addition to its use described here, the drill carriage can be arranged as a rail-laying truck. In conclusion, the writer wishes to acknowledge the help given him by Mr. Hoelfeldt-Lund and Mr. Roseg in gathering the material for and in passing upon this article.

ESTIMATED COST PER FOOT OF RAILWAY TUNNELS OF 300 SQ. FT. SECTION

BASED ON DRIVING METHOD USED AT GRONG TUNNEL.

(NO LINING—DRIVING FROM ONE PORTAL).

	Length of tunnel, ft.	6,550		8,200		9,800		11,500		13,100		14,750		16,400	
	Working shifts per day	2	3	2	3	2	3	2	3	2	3	2	3	2	3
	Years needed for completion (approximate)	2	1¼	2½	1½	2¾	2	3¼	2¼	3¾	2½	4¼	2¾	4¾	3
	EQUIPMENT INVESTMENT Machines, materials, houses (100% depreciation)	$18.6	18.6	15.7	16.5	14.6	15.2	13.5	13.7	13.0	13.5	12.1	12.5	11.4	11.8
OPERATING COSTS	Wages (Avg. $4 per shift)	$15.4	14.2	15.5	14.3	15.5	14.3	15.6	14.3	15.6	14.3	15.6	14.4	15.6	14.4
	Explosives, caps, fuses (Avg. dynamite consumption 34 lbs. per ft.)	$11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11 4
	Miscellaneous supplies, machinery, repairs	$6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6 5
	Electric power (Based on $40 per kw. yr.)	$2.9	2.2	2.8	2.2	2.9	2.4	2.9	2.4	3.0	2.5	3.0	2.6	3.2	2 7
	Clearing of tunnel, roof, and bottom	$1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1 8
	Total (approximate)	$56.5	54.5	53.5	52.5	52.5	51.5	51.5	50.0	51.5	50.0	50.5	49.0	50.0	48 5

300,000 Foresters Take to Our Wooded Areas

C. H. VIVIAN

THE MAJESTY OF TREES

A second-growth stand of poplar and red oak in the Shenandoah National Forest of Virginia.

A PEACETIME army, 300,000 strong, encamped in every state of the Union except one, is entering upon the second half of its first year in the field. This army is one of industry rather than of war. It is concerned with construction, not destruction. Instead of guns and other instruments of conflict it uses picks, shovels, axes, rock drills, tractors, and kindred implements and machines. Reveille is sounded by a whistle in place of a bugle. The manual of arms, setting-up exercises, brass bands, parades, and other manifestations of military life are conspicuously missing. In short, it is an army only in name and in the manner in which it was mobilized and is being housed. This army is the Civilian Conservation Corps, more familiarly the C. C. C.

The organization was called into being last April as one phase of President Roosevelt's program of economic recovery. As stated at the time, it was conceived primarily to offer a means of "restoring confidence and building men." Its more material purpose was "to protect, develop, and perpetuate our existing forests." When it was created, there were hundreds of thousands of jobless young unmarried men, principally in the towns and cities. In the 160,000,000 acres of our national forests and in the expansive areas of hundreds of state parks there was much needed conservation work to be done. The C. C. C. movement was a practical plan for bringing the two together. It was successful from the start; and there is reason to believe that it will continue to operate until such time as the farms, industries, and offices of the country are able to absorb these civilian soldiers.

The C. C. C. is composed essentially of single men between the ages of 18 and 25 years, of whom there are approximately 250,000 enrolled. They are paid army wages of $1 a day plus clothing and subsistence, with provisions for sending home up to $25 each month to help make their families self-supporting. In addition, there are included some 25,000 older men living in the areas where the work is being carried on. These were selected for their experience and knowledge of work in the woods. Further provision was made for enrolling 25,000 war veterans and not more than 14,400 Indians, both of which classes were to have their own separate and distinct organizations. The whole movement was termed the Emergency Conservation Work Project, and Robert Fechner was appointed by the President to be its director. He is assisted by an advisory council composed of F. A. Silcox, chief forester of the U. S. Department of Agriculture; Arno B. Cammerer, director of the National Park Service; W. Frank Persons, of the Department of Labor; and Col. Duncan K. Major, of the War Department.

The men were selected in various parts of the country by the Department of Labor. The War Department enrolled them, transported them to army posts to be outfitted and conditioned, and then moved them to the scattered forest camps which had meanwhile been built under its direction. The Department of Agriculture, acting through the Forest Service, selected the camp sites in national forests, furnished the equipment needed, and has since supervised the work. Many of the camps were established in state parks, and their locations were determined by the respective states concerned. The Department of the Interior, through its National Park Service and its Indian Service, has general supervision over the activities carried on within national parks and Indian reservations.

Although the army plays a prominent part in the plan, no effort is made to enforce military discipline. Enrollment is entirely voluntary, and no army obligation is involved. Three commissioned officers and three noncommissioned officers of the regular army are attached to each camp. They are charged with the responsibility of operating the camps and looking after the health and well-being of the men. Their control exists, however, only during the nonworking hours. For 40 hours

Note—Many of the photographs are reproduced through the courtesy of the U. S. Forest Service.

TYPICAL TASKS OF THE C.C.C.

These pictures portray a few of the many types of work done by this civilian army of 300,000. The boys in No. 1 are making war on the pine beetle. In No. 2 a bridge on a sheep driveway in the Sawtooth National Forest, Idaho, is being repaired. A glimpse of roadbuilding, which is a leading activity, is given in No. 3. The picture was taken in the Snoqualmie National Forest, Washington. No. 4 shows a crew cutting a fire-break in the Cleveland National Forest, California. The treating of telephone poles is pictured in No. 5.

each week actual work is carried on under the direction of representatives of the Forest Service.

At full strength, each camp is made up of 200 men. To facilitate organization, the camps are distributed over the country in zones corresponding to the nine corps areas into which the army is divided. Within three weeks after Congress had enacted the enabling legislation, the first camp had been established near Luray, Va., in the George Washington National Forest. In less than three months all the enrolled men were in camps.

The initial period of enrollment was set at six months; but this was later reduced by one month in order that replacements might be made and winter camps constructed before cold weather set in. Approximately 126,000 men withdrew from the corps when their period of enrollment expired last October, and these have since been replaced. During the summer months, tent camps were established in forested areas in every state except Delaware; and of the 1,468 camps set up, 918 are being occupied this winter. Five hundred and fifty camps were abandoned, and an equal number of new sites selected in sections of the country having more favorable winter climates.

Except in the South, all or part of the winter quarters are of wood. Fifteen thousand buildings, made up of 300,000,000 feet of lumber, were speedily assembled by 40,000 carpenters working in 46 states. The cost was about $20,000,000, divided almost equally between labor and materials. This construction program is reported to be the largest ever carried out by the army in peacetime. From two to eight buildings were erected in each camp, depending upon the winter climate to be encountered. To equip the camps, the Government bought 25,000 heating stoves, 5,000 cooking ranges, 800 electric-lighting plants, and 17,100 fire extinguishers. Wherever possible, materials and equipment were purchased in the respective camp areas in order to stimulate business over a wide section. At the same time, the army issued more than 3,300,000 articles of winter clothing, including windbreakers, gloves, overshoes, underwear, heavy socks, wool and corduroy trousers, and heavy shoes.

So much for the general background of the movement. Now let us consider some of the things that this peacetime army is doing. Because the activities are being carried on in forest areas, the popular conception is that these men are primarily foresters and that their work is chiefly concerned with the trees, themselves. This is so only to a degree, although it is true that all the operations contribute either directly or indirectly to the conservation of our wooded areas. Actually, the activities are of many kinds and types, which, taken as a whole, represent the backlog of work which the regular Forest Service has been unable to handle with its limite personnel and finances.

HOW FORESTS SERVE MANKIND

Wood is a leading crop, but it is only one of numerous sources of revenue from the forests. The bottom picture shows a small sawmill operating in a southern forest. Tannic acid and other useful products are derived from the barks of certain trees. A procession of wagons hauling bark to market is seen in the center. Millions of sheep graze annually in our national forests (top).

Cultural work, under which are grouped the various operations having to do with the planting and nurture of trees, is, of course, an important function, and in some camps a great deal of it is being done. By and large, however, most of the efforts are being expended along other lines which are equally desirable but not so closely related to the actual culture of the forests.

Prior to the establishment of the camps it was determined that the work should include the doing of those things which would "help to protect, develop, and perpetuate existing forests; help to prevent soil erosion, which aggravates damage from floods; help to

WHERE THE AIR IS LIGHT

Drilling with a "Jackhamer" in the Boise National Forest, Idaho. Many of our national forests are at high elevations, and in such locations 2-stage, air-cooled, portable compressors, like that shown here, constitute economical sources of power.

establish new, and reëstablish old, forests." When put into effect in the field, this policy expanded in manifold ways. As the national and state forest areas are extensive and interspersed with many tracts of privately owned land, the work knows no boundaries. If certain things are considered to be to the interest of the public at large, they are carried out regardless of their exact location but subject to the approval of the states or individuals who own the land concerned.

It would require a large proportion of one of our pages merely to list the various types of work being done. Throughout the country, as a whole, a considerable share of the work is being devoted to the construction of roads and trails. These avenues of communication are designed to open up various forested areas so as to make it easier to reach all parts of them. Their primary purpose is to reduce fire losses by providing means of getting men and materials to burning sections without delay. They are also intended to facilitate logging operations and other forest industries. Some of these roads will be shorter than existing routes for general travel and will be widely used by the general public, although such usage is of secondary consideration in their planning and construction.

Another important phase of fire-prevention work is the cutting of fire lanes or breaks. These are cleared strips through the forests designed to act as fire stops and also to afford ready access to burning areas for the fire-fighting crews. The establishment of lookout stations and towers, the erection of telephone lines, the placing of caution signs to smokers and campers, and numerous similar activities also contribute to the lessening of fire hazards.

Since the national forests are maintained for the avowed purpose of providing the greatest benefit to the greatest number, an important part of the work consists of improving their recreational features. This involves such things as the creation of camp sites; the erection of tables, benches, stoves, and sanitary structures; the development of adequate water supplies; the construction and marking of trails; and the provision of facilities which will promote the propagation of game and fish. Within the area covered by a single camp the schedule of operations often calls for the building of as many as 100 dams of varying heights to control stream flow and thereby create favorable conditions for the growth of game fish. In numerous instances, dams of considerable size are projected for the purpose of creating lakes suitable for bathing, boating, and fishing. Sometimes such dams are large enough to impound water in sufficient quantities to supply neighboring towns and cities.

In some sections of the country the prevention of soil erosion constitutes a leading activity of the camps. This calls for the construction of low dams at frequent intervals along waterways which exert a destructive scouring action following storms. Hand in hand with this work goes the improvement of grazing areas to prevent excessive washing away of the top soil. This includes not only the replanting of overgrazed areas but also the education of the range users so that they will appreciate the importance of keeping their stock off these lands until nature has had a chance to renew their vegetation. It is interesting to note in passing that a considerable portion of the work being done by the 14,400 Indians enrolled in the C. C. C. is of the erosion-prevention type.

Cultural work embraces a wide range of operations. Trees, like flowers or vegetables, have to be cultivated if they are to flourish. The weak and sickly specimens must be removed to give the sturdier ones room to grow. Old, diseased, and deformed trees must be taken out. In heavy stands of timber, thinning is essential to healthful growth even when all the trees are normal. In all our forests the trees are afflicted with various diseases, and there is a big job of surgery to be done. The white-pine forests across the northern part of the country from New England to the Pacific Coast are preyed upon by a fungus disease known as blister rust. It first attacks currant and gooseberry bushes, and spreads from them

PRESERVING WAR SHRINES

A glimpse of the Gettysburg battlefield, immortalized by Lincoln. Several hundred C.C.C. members worked there last autumn restoring old structures and doing general clean-up work.

FIRE-FIGHTING UP TO DATE

Logging operations call for locomotives and increase the fire hazard, but they also provide speedy transportation of equipment for fighting flames. This crew is putting out a small fire in the Shenandoah National Forest with modern apparatus.

to the pines. The obvious treatment is to remove and destroy the bushes. Similarly, other tree infections are eradicated. Harmful insects abound in the wooded areas and these, too, must be eliminated. Boring beetles, alone, are charged with doing millions of dollars worth of damage annually. The gypsy moth, likewise, is a prevalent enemy of tree life, and its activities must be checked. Cultural work requires some knowledge of forestry, and is carried on only under the supervision of competent overseers selected from the regular Forest Service personnel. In some sections rodent control must be practiced to improve and protect grazing lands.

The removal of fire hazards is, naturally, a primary activity in many of the camps and probably will become more intensive as additional access roads are completed. Both burned-over areas and green forests are filled with dead trees, snags, dry leaves, and other matter, which require only a spark to set them afire. These hazards are cleared out, piled up and burned—the work being carried on first along roads and around frequented camp areas and then progressively farther in the forests.

Even from this sketchy outline it will be readily apparent that the C. C. C. work is along broad lines and that, in addition to furnishing healthful and remunerative employment for thousands of unoccupied young men, it is contributing something of permanent value to the nation by insuring wider and more beneficial use of our forests. As to just how helpful the movement is considered by those whose life work is in the forests, we can cite from a report by the assistant regional forester upon the achievements of the C. C. C. in the national forests of California.

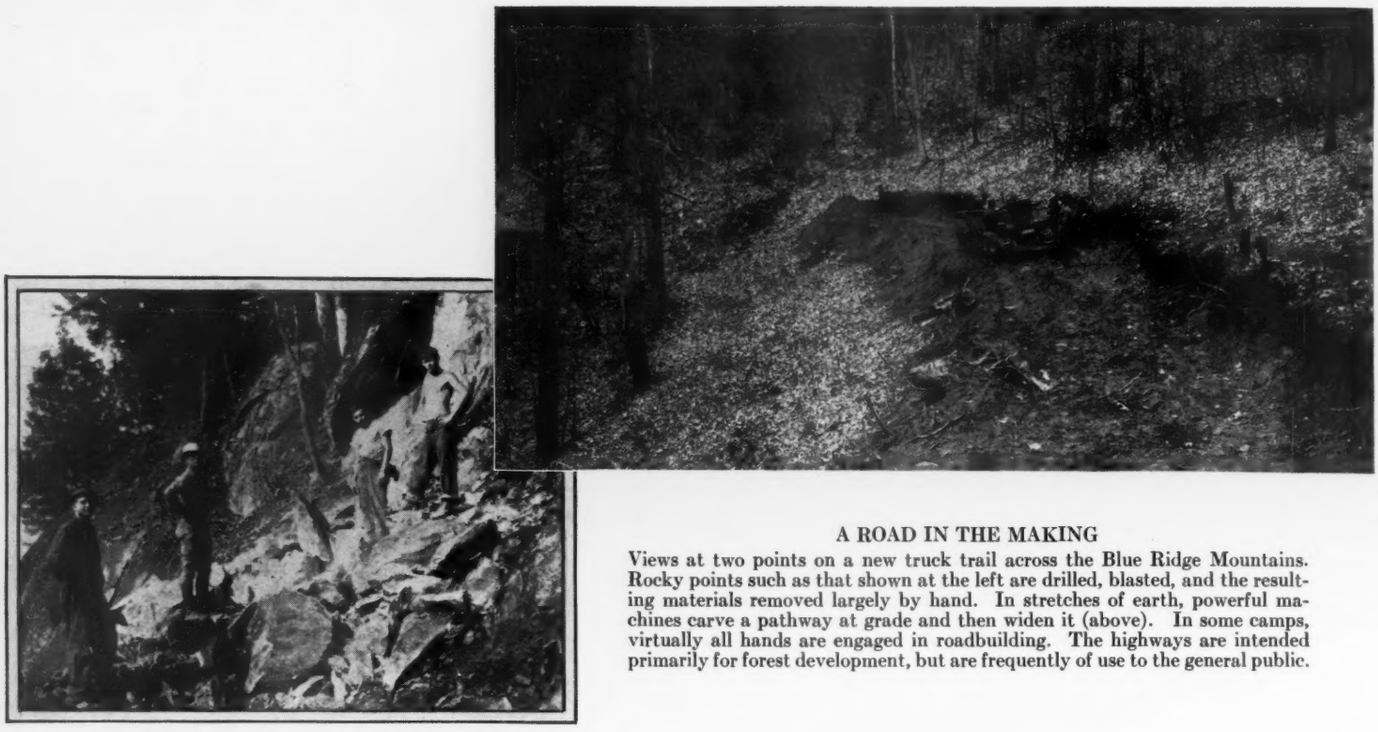
The work in that state has ranged all the way from the building of simple dams for erosion control to the construction of a 400-foot suspension bridge across the Klamath River, and has included all the activities previously mentioned in this article. More than 1,170 miles of roadway have been built and 1,680 miles maintained. Fire hazards have been reduced on more than 100,000 acres, and rodent control has been practiced on more than 550,000 acres. It is estimated that the accomplishments up to the end of October were equivalent to about three years of normal Forest Service work conducted upon the scale which prevailed before the depression years. Based upon the plans as outlined for the continuation of the camps, it is estimated that eighteen months of their work will equal ten years of routine operations. The need that existed for this work is brought out by the statement that eighteen months of C.C.C. activities would just about be long enough to make the essential improvements in ranger dwellings, equipment storehouses, lookout structures, fireman stations, telephone lines, drift fences, and other structures of this nature. Such a period of service would, however, prove insufficient to develop an adequate system of roads. Taking account of the proposed work of the C.C.C. during 1934, it is predicted that some 6,000 to 7,000 miles of additional roads will still be required in the California forests.

The same report is equally enlightening as to the fire-protection benefits that have resulted. Although 1933 weather conditions were considered fully as hazardous as those for the four preceding years, burned areas fell from an average of 184,000 acres to 71,000 acres, or a decrease of about 63 per cent. Because of the availability of C.C.C. men for fire-fighting purposes, the expenditures from Forest Service funds for combating fires were only about one-eighth of the normal amount. The resultant saving of several hundred thousand dollars was sufficient to defray a substantial part of the cost of maintaining the camps.

Significant in the report is the statement that the number of incendiary fires in 1933 dropped to 116, as compared with a 5-year average of 254. Analyses of individual fires disclose that three blazes in inaccessible areas were responsible for two-thirds of the burned area in 1933. Because of their remoteness, crews had to travel from five to thirteen hours to reach them, and during these intervals the flames spread to such an extent that

IN VIRGINIA'S BLUE RIDGE

Substantial buildings house the C.C.C. during the cold weather. Approximately 15,000 structures such as these have been built in 46 states. The camp shown is near Lyndhurst, Va.



A ROAD IN THE MAKING

Views at two points on a new truck trail across the Blue Ridge Mountains. Rocky points such as that shown at the left are drilled, blasted, and the resulting materials removed largely by hand. In stretches of earth, powerful machines carve a pathway at grade and then widen it (above). In some camps, virtually all hands are engaged in roadbuilding. The highways are intended primarily for forest development, but are frequently of use to the general public.

they could be brought under control only with difficulty. Roadways such as are now under construction would have enabled men and equipment to get to the burning areas quickly.

Having thus delineated the general features of the program, it might prove of interest to present a more intimate view of one of the C.C.C. camps. The unit selected for visitation happened to be Camp F-8, located in the George Washington National Forest about twelve miles from Waynesboro, Va., and in the heart of the Blue Ridge Mountains. It was the second camp established in Virginia, and among the first in the country. This national forest contains about 640,000 acres. The crop trees—that is, those which are commercially used—are oak (six varieties), hemlock, pine, and poplar. A considerable portion of the forest lies upon the slopes of mountains which are rather precipitous as mountains go in the eastern section of the country. These uplands are quite heavily wooded and are so grown over with smaller vegetation that they are difficult to traverse during the summertime. Roadways are comparatively scarce, and for that reason their construction is one of the chief pursuits of the eleven camps that have been located in this forest. In the camp under discussion, roadbuilding has received virtually all of the attention save for six weeks devoted to cultural work by 40 men. Because of the character of the activities involved, a man experienced in highway building and familiar with various types of forest construction work fills the post of project superintendent.

The visitor finds the camp in transition from summer to winter garb. Pine-board buildings, weatherproofed with tarred paper and reminiscent of the structures seen in various army posts during the war days have recently replaced tents. The recreation hall has not yet been erected, but is about to be started. This will be a 20x140-foot structure with reading and writing rooms, a library, and a large room suitable for lectures and entertainments.

The mess hall is a long building with tables and seats sufficient to accommodate all members of the camp at one time. One end of it is screened off to separate the kitchen and commissary from the main dining room. An army mess sergeant is the major-domo there. Five days' rations are held in reserve at all times for use in case of emergency. All food supplies are bought by the army personnel in charge of the camp. Some of them are secured locally, others come from army posts. Before the mess hall was available, the men came to the kitchen with standard army mess kits and formed a line to receive their food. Now they have a supply of tableware, and their food is served to them when they are in camp. At noontime most of them are usually several miles away, and hot food is taken to them in trucks.

The barracks house 40 men each and are equipped with iron beds. Convenient to the sleeping quarters is a building containing sixteen shower baths and rows of washbasins over which are mirrors for shaving. Another structure serves as a supply depot for clothing and small tools which are used in the forest. Each man who takes out tools is responsible for their return. Offices, sleeping quarters, and dining facilities for the administrative personnel occupy a separate building. Still another is divided up into a hospital at one end and sleeping quarters for the Forest Service personnel at the other end. A scattering of workshops, sheds, etc., completes the winter camp.

The rising whistle blows at either 6:30 or 6:45, depending upon the season. Breakfast is served at seven o'clock and sick call comes at 7:30. At eight o'clock the men climb into trucks and are taken to the scene of their day's labor. As already stated, this particular camp is chiefly occupied with the building of roads, or truck trails, to be technically correct. We learn that a truck trail is a form of forest highway designed primarily for the passage of trucks. Such roadways are limited to 12 feet in width, and are not considered good enough to bear the name highway. Upon being taken on a tour of inspection of the work currently done, we find, however, that these roads are of good alignment and that they are carefully built.

The road we travel ascends the north side of the mountain chain on a grade which is moderate in most places but rises as high as 14 per cent. We cross the main ridge at an elevation of 2,300 feet above sea level while our conductor points out to us a fire lookout station situated on top of Bald Mountain some 1,200 feet above us. A lookout is maintained there 24 hours a day to give warning of any evidences of fire which he may discover. Down at the camp a circle has been drawn around the spot on the map which designates the apex of Bald Mountain. This circle is divided into the 360 degrees which comprise it. Using a similar circle, the lookout telephones the exact bearing of any smoke he discerns, and this enables those in the valley below to determine its location with accuracy and to move a fire-fighting crew to the area without delay.

We proceed down the south slope of the mountain range. In the distance, 1,400 feet below us, we can see a level plain, and beyond our vision lies Lynchburg. The 9-mile road now being built will meet an existing highway at Nash, thereby forming a direct route from Waynesboro to Lynchburg and shortening the travel distance by from 30 to 35 miles. It will, therefore, probably receive considerable commercial and general traffic, although its primary purpose is to open up the area traversed.

After traveling two or three miles we reach a point where the road is no longer negotiable

CAMP BLACKSMITH SHOP

Many a lad that never saw a rock drill until he enrolled in the C.C.C. is running one now. The picture at the right shows a corner of the blacksmith shop at Camp 8 in the George Washington National Forest, Virginia. Drill steels are sharpened here for several neighboring camps. Compressed air for this work is supplied by the portable shown above. Standing beside it is the camp's patriarch. Past 70, he is hale and hearty, thanks to a lifetime spent in the woods.

with an automobile, and we walk on down the line where construction is being done and then on ahead in the lane that has been cleared through the timber to mark the way the road-builders will follow. In places the line runs through a hard granitic rock, and in such stretches a rock drill comes into play. Our guide shows us an Ingersoll-Rand R-39 "Jackhamer" which is doing all the drilling on this 9-mile stretch and which has previously served a similar purpose on more than five miles of road already completed several miles away.

All drill steel is transported to the camp for reconditioning, and a truck makes two trips daily for that purpose. The blacksmith shop is equipped with a No. 34 sharpener which is operated by a Type 20 air compressor mounted on a truck. Steels are heated for forging in a coke-fired furnace. This shop reconditions drill steels for other nearby camps, which send it in a ton at a time.

Where there is not sufficient rock to require drilling, a powerful machine known as a "trailbuilder" assumes most of the burden. It consists of a tractor on crawlers, upon the front of which is mounted a heavy blade which can be tilted or elevated as desired through the operation of oil-pressure pistons. This piece of equipment can be made to perform almost incredible maneuvers in the hands of a skillful and daring operator. It cuts deep into the side of a hill, pushing before it dirt, bowlders, bushes, and tree stumps. If a rock face stands in its way, it goes around the obstruction and continues its efforts beyond that point. It negotiates steep slopes with comparative ease, and threads its way through the timber in an almost unbelievable manner. First it defines a narrow trail, then widens it a little at a time.

Save for the one rock drill and the trail-builder, mechanical equipment is little used. Rocks which remain on the roadway following blasts are barred or carried to the outside edge and allowed to roll down the slope. Picks and shovels also come into play for the moving of both rock and dirt.

The enrolled men are organized in sections of 40 each. A section leader, selected from the enrolled men and paid $45 a month, directs the work of each group. Under him are two subsection leaders, each in charge of twenty men and paid $36 a month. The regulations permit the designation of ten enrolled men to receive $45 a month and sixteen men to receive $36 a month. There is, accordingly, an incentive to work and study which will lead to advancement. A truck-trail foreman has general supervision of the roadwork. He is a member of the Forest Service, as distinguished from the enrolled, and is paid $110 a month less the 15 per cent deduction which now applies to Government salaries. There are several men in this classification in each camp. It not infrequently happens that a member of the enrolled corps shows such aptitude for the work that he is advanced successively until he has reached this maximum rating.

Our tour of the truck trail over, we return to the camp. There we find that 23 men, comprising the camp overhead, have remained there during the day. This number is required for maintenance, cleaning, preparation of food, and miscellaneous tasks. We are told also that 40 men are kept available at all times to answer fire calls. We are shown a small cylindrical metal housing where fire-fighting equipment for twenty men is kept sealed so that it will be instantly ready for loading into a waiting truck which will carry it to the burning area reported by the lookout.

The actual working hours in the field range from six to seven a day, depending upon the distance of the scene of operations from the camp. The time required for transportation is taken out of the prescribed 40 hours of work each week. This means that for 128 hours each week, or more than 75 per cent of the time, the men are under the supervision of the army personnel or are left to their own devices. Actually, their time during nonworking hours is pretty much their own. Necessary routine camp work is done by the regular overhead contingent previously mentioned. On stormy days, when the men cannot carry on field work, all of them are subject to the jurisdiction of the army personnel, and on such occasions they are kept busy cutting firewood or performing miscellaneous tasks.

The camp has its educational side as well as its more material aspect. Classes of various sorts are conducted evenings in the mess hall or the recreation building. Some of the enrolled men cannot read nor write, and these receive elementary instruction. Drafting and other rudimentary courses in engineering are taught by the army officers attached to the camp or by other qualified persons. Classes in the elements of forestry are carried on by Forest Service representatives. Instruction is also given in some mechanical lines, including blacksmithing, automobile repairing, etc. Spare time not utilized in this way is occupied much as normal American men of the same ages spend their hours of leisure. Some of the men have their own automobiles, and these and the camp trucks, of which there are eight, are available to take them to nearby towns. On Sundays, the entire camp is transported to Waynesboro where the proprietor of a motion-picture house presents the following week's program free of charge.

All in all, the C.C.C. camps seem to be doing a worth-while job both in molding better citizens and in furthering the conservation and greater utilization of one of our foremost natural resources.

Centrifugal Water-Vapor Refrigeration Achieved

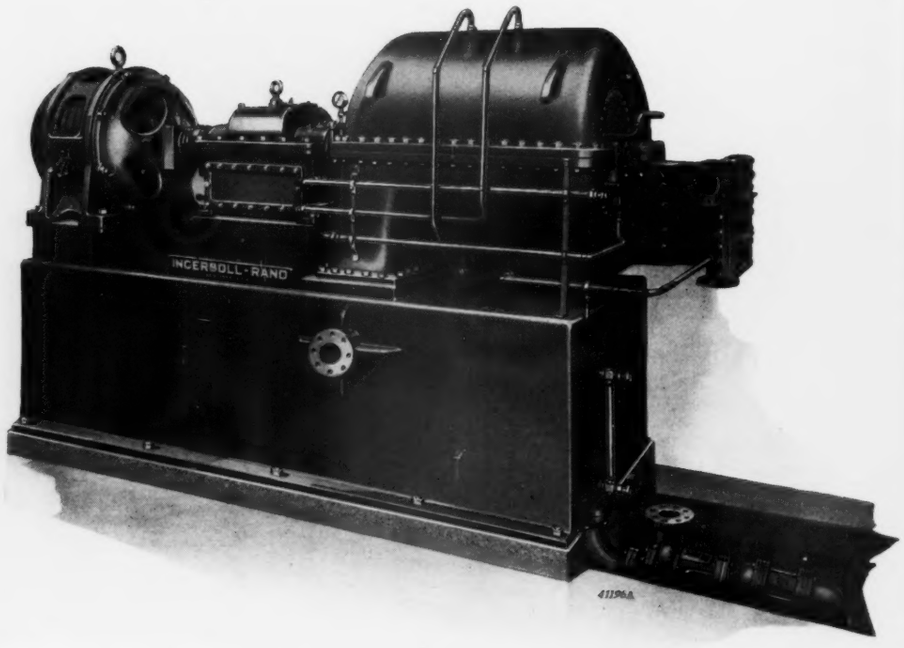
IN OUR June, 1933, issue was a description of steam-jet refrigerating equipment which is now coming into widespread usage in the manufacture of cold from water vapor. In such apparatus the refrigerating effect is obtained by creating a high vacuum and thereby causing water to boil or "flash" into vapor at temperatures below 50°F. as compared with its normal sea-level boiling point of 212°. The heat required to effect this evaporation is drawn from a reservoir of water, which is consequently cooled.

Curiously enough, the first refrigerating machine was of the vacuum type. It was invented in 1755 by a Scottish physician, Dr. William Cullen. This apparatus used an air pump to exhaust the air from a receiver in which water, ethyl alcohol, nitrous ether, or other fluids were evaporated. Doctor Cullen's device never went beyond the laboratory stage because insuperable obstacles stood in the way of maintaining in commercial apparatus the high vacuum that was needed. The evolution of refrigerating equipment proceeded along different lines; and they employed refrigerants which are vaporous at ordinary pressures and temperatures. In other words, it was easier to compress and to cool these into liquids and allow them to boil back into volatile form than it was to create a sufficiently depressed atmosphere so as to cause water to evaporate at low temperatures.

The recognized difficulties of utilizing water vapor as a refrigerant were responsible for the dismissal of the process from practical consideration for the better part of two centuries. But highly efficient steam-jet boosters made their appearance a few years ago and furnished a means of producing the high vacuums that were required. This resulted in the development of refrigerating apparatus of the steam-jet type. Not only are such systems workable but they possess some advantages over conventional systems; and under certain conditions, notably where there is sufficient steam, they are more economical to operate than systems of the long-established type.

Now another epochal advance has been made, this being the practical and effective water-vapor refrigerating unit which obtains the essential vacuum by means of mechanical equipment. This has been achieved after years of experimentation and painstaking effort to overcome the numerous problems involved. Their solution was materially furthered because Ingersoll-Rand Company—the organization in question—had on its staff specialists in the lines concerned. The new machine is built in standard sizes ranging in capacity from 50 to 300 tons of refrigeration. It consists mainly of an evaporator, a centrifugal compressor and driver, a condenser, and the necessary pumping equipment. The evaporator serves as a base for the compressor, an arrangement that saves space and makes for efficiency.

The operation of this apparatus, which is known as the centrifugal water-vapor refrigerating unit, is simple. Water which is to be cooled is sprayed into the evaporator. The centrifugal compressor, having its intake connected to the evaporator, pulls a high vacuum on the chamber and thereby causes some of the sprayed water to flash into vapor. The compressor withdraws this vapor, compresses it, and discharges it into a condenser, where it is condensed. The required vacuum in the condenser is maintained by either a steam-jet or a mechanical vacuum pump.



CENTRIFUGAL WATER-VAPOR REFRIGERATING UNIT

Engineers will find it interesting to consider some of the problems that had to be solved in the development of this type of unit. To obtain a boiling or evaporating temperature of 50°F., it was necessary to secure and to maintain a vacuum of 29.64 inches of mercury, or within 0.36 inch of an absolute vacuum. The water had to be introduced; part of it vaporized; the vapor and the water separated; the chilled water withdrawn from the bottom of the evaporator at a suitable rate of flow; and the vapor directed to the compressor. The disruptive force of evaporation; the areas and velocities required; and many other problems concerning the flow of water and vapors had to be worked out.

Little or no data were available regarding the behavior of highly attenuated water vapor, and its compression was an uncharted field of research. Every pound of water evaporated became transformed into 1,700 cubic feet of vapor, which meant handling approximately 35,000 cfm. to secure 100 tons of refrigeration. This had to be compressed sufficiently to make possible its condensation with water at temperatures ordinarily available. The discharge pressures required—from 28 to 28½ inches of vacuum—were in themselves very low, but they were from 4½ to 6 times greater than the suction pressure of 0.36 inch. These conditions were comparable to taking air at atmospheric pressure and compressing it to from 50 to 75 pounds gauge pressure. A centrifugal air compressor capable of handling 35,000 cfm. would have required as many as ten stages of compression and from 5,000 to 7,000 hp. Moreover, the limited knowledge concerning the coefficients of compression of water vapor seemed to indicate that, for the ranges of compression involved, it would require more stages than would air. Besides, the machine had to be air-tight at the casing joints and stuffing boxes. Just adapting a standard centrifugal air compressor would have been impractical and costly.

The numerous problems that arose were successfully solved by building successive experimental units and working out entirely new designs of commercial machines well qualified for the work of compressing highly attenuated water vapor.

Centrifugal water-vapor refrigeration is finding wide application in air-conditioning and in industrial-cooling services that require temperatures of 45 to 50°F. It has the advantages of desirable partial-load characteristics, economy, and safety. It is especially suitable for air conditioning because it uses no chemical refrigerants that are a potential hazard and must be replenished periodically because of unavoidable leakage.

The new refrigerating unit is adaptable to working conditions. Where steam is available it can be used with a turbine to drive the centrifugal compressor operating either condensing or noncondensing: where steam is not available, an electric motor is the driver.